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Compaq Computer Corporation

ISSD Technology Communications

PCI Hot Plug Technology with Microsoft Windows Architecture



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As an increasing number of companies migrate their business-critical applications to industry-standard servers, the need for high-availability solutions to minimize system downtime is increasing. Compaq, the world's leading server provider, has historically taken a leadership role in developing industry-standard technologies. With the development of PCI Hot Plug technology, Compaq strengthens its role in providing high-availability solutions for the enterprise.

Microsoft Corporation is a world leader in the development of operating system software, and Microsoft Windows is one of the most widely used operating systems in the world. Because of Microsoft's expertise in this area, Windows is perfectly suited for integration of PCI Hot Plug, especially Compaq's leading implementation. Compaq and Microsoft have worked together to deliver PCI Hot Plug capabilities to Compaq customers using Windows NT Server 4.0 and Windows 2000 Server operating systems.

This brief outlines Compaq's PCI Hot Plug implementation strategy for Microsoft Windows operating systems. It also describes the hardware components of Compaq's implementation and explains the architectures of the software solutions Compaq developed for the Windows NT Server 4.0 and Windows 2000 Server operating systems.

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PCI Hot Plug Technology with Microsoft Windows Architecture

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INTRODUCTION

High availability is critical in today's 7x24 global enterprises. Few businesses can tolerate extended downtime, and companies that conduct revenue producing transactions across a network cannot afford to lose applications or data for even a few seconds. PCI Hot Plug is a cost-effective, industry-standard solution that provides customers increased system availability and nonstop serviceability.

Compaq pioneered PCI Hot Plug and realized customers would benefit far more if a standard were developed by which components from multiple vendors could work together. Compaq chaired the PCI Special Interest Group and worked with leading adapter vendors and operating system (OS) developers to develop the standard specification. This effort allows customers to move forward in implementing this technology with greater flexibility.

PCI Hot Plug provides the ability to insert and remove PCI adapter cards without having to shut the system down. This capability allows for several implementations, including **hot replace**, replacing adapter cards in "hot systems"; **hot upgrade**, upgrading existing adapter cards with new versions of cards and drivers; and **hot expand**, adding previously uninstalled cards and associated driver software into the system.

PCI Hot Plug technology represents a significant advance in fault-tolerant systems. To provide even greater benefit, PCI Hot Plug technology can be combined with other high-availability solutions presently available from Compaq such as Recovery Server Options, Redundant Netelligent Network Interface Controllers, hot-pluggable power supplies, hot-pluggable fans, and hot-pluggable SCSI drives.

The Compaq technology brief *PCI Hot Plug Technology*, document number ECG080/0698, outlines additional details of Compaq's strategy in developing this technology.

COMPAQ IMPLEMENTATION STRATEGY

PCI Hot Plug functionality requires both hardware and software components. A fully capable hot-plug system includes the hot-plug system hardware, a hot-plug aware OS and user interface, hot-plug system drivers, and hot-plug capable device drivers.

It is important to note that while the PCI specification¹ identifies the technical requirements of a hot-plug capable system, it does not define the specific hardware and software implementations of this technology. Compaq provides a robust hardware implementation that eases management of hot-plug events while the software components required for PCI Hot Plug functionality are normally provided by OS developers.

The software interface that Microsoft will eventually support for PCI Hot Plug in the Microsoft Windows 2000 Server OS is the Advanced Configuration and Power Interface (ACPI) specification². By hiding the hardware implementation of each hot-plug controller, ACPI enables the OS to control the amount of power given to each device attached to the computer and allows Microsoft to generically support PCI Hot Plug. However, due to time-to-market issues, Microsoft will not support PCI Hot Plug—even through ACPI—under the initial release of the Windows 2000 Server OS. Microsoft's development of PCI Hot Plug will begin following the initial

¹ Version 2.2 of the PCI specification, announced January 25, 1999, can be requested from the PCI SIG website at <http://www.pcisig.com>.

² For more information on the ACPI specification, see the ACPI website at <http://www.teleport.com/~acpi/>.

release, and support will be available in a later release of the Windows 2000 Server OS as soon as PCI Hot Plug support is ready.³

To give PCI Hot Plug functionality to Compaq customers using Microsoft Windows in the interim, Compaq developed software solutions for both the Windows NT Server 4.0 OS and the Windows 2000 Server OS. PCI Hot Plug technology for the Windows NT Server 4.0 OS provides the ability to hot replace PCI adapters. Compaq's Windows 2000 Server OS PCI Hot Plug software adds hot upgrade and hot expansion functionality.

As a leader in industry-standard technology development, Compaq is contributing to the development of the ACPI implementation and future specifications. This will enable the industry to take advantage of Compaq's experience and expertise while ensuring that Compaq customers are provided the most up-to-date technologies. Several Compaq servers are currently ACPI compliant, and as ACPI evolves to offer customers a more robust PCI Hot Plug software solution, Compaq will migrate its PCI Hot Plug solution accordingly. This will ensure that customers receive the highest levels of availability while maintaining compatibility with Microsoft OSs.

SYSTEM HARDWARE

In the specific implementation that Compaq developed, the PCI Hot Plug hardware isolates a single PCI slot from all other devices on the PCI bus. Compaq's PCI Hot Plug system hardware performs two main functions:

- Powers down a single adapter slot, allowing insertion and removal of adapters
- Protects the system and other adapters from the electrical effects of hot-plug operations

Hot-Plug Controller and Slot-Specific Power Control

The hot-plug electronics designed by Compaq consist of two separate elements: the hot-plug controller and the slot-specific power control. Both of these elements are provided in a Compaq developed application-specific integrated circuit (ASIC). Compaq designed its ASIC to manage the following components:

PCI Bus. The hot-plug controller communicates with isolation devices on the PCI bus to electrically isolate a single PCI slot from the rest of the system. Slot isolation permits insertion or removal of an adapter without interruption to the server or other active adapters.

Power. The controller receives a command from the OS to power up or power down a single PCI slot. To perform this function, the controller uses the slot-specific power control. The slot-specific power-control electronics allow the proper power sequencing on the PCI bus and guarantee safe control of the power to the individual PCI adapters.

Slot LED Indicators. The hot-plug controller also governs the slot LEDs. In Compaq's implementation of hot-plug hardware, each slot has a green and an amber LED to indicate slot status. The green LED indicates power to the slot and flashes while performing a power state change; the amber LED indicates that the slot requires attention.

PCI Hot Plug Button. This feature is available only on Compaq's PCI Hot Plug servers manufactured since August 1998. The button is pressed to signal the software to initiate a power state change. While the button is more convenient, the same functionality is also provided through the software interface. Each slot has its own button to indicate which slot is to be addressed by the supporting software.

³ Check <http://www.microsoft.com/hwdev/pci/hotplugpci.htm> for more information on Microsoft's PCI Hot Plug support.

SOFTWARE ARCHITECTURE

As stated earlier, Compaq developed software solutions for both the Windows NT Server 4.0 OS and the Windows 2000 Server OS to deliver PCI Hot Plug functionality for Compaq customers using these Microsoft OSs. PCI Hot Plug technology for the Windows NT Server 4.0 OS provides the ability to hot replace PCI options. PCI Hot Plug technology for the Windows 2000 Server OS enables both hot upgrade and hot expansion capabilities. Both software architectures are described in the following sections.

Windows NT Server 4.0 Operating System

PCI Hot Plug software for the Windows NT Server 4.0 OS includes the following components:

- Compaq PCI Hot Plug Utility – primary user interface for managing the PCI Hot Plug buses on the local system as well as on remote systems accessible over the network
- Compaq Remote Monitor service – OS support element that enables control of the hot-plug hardware
- System Management driver – OS support element that enables control of the hot-plug hardware
- Hot-plug-aware device driver – enables the system to halt operations on a specific controller prior to removing the controller

Using Remote Procedure Calls (RPCs), the PCI Hot Plug Utility manages the PCI Hot Plug slots on the local system or any system accessible on the network. The use of RPCs allows management of all the PCI Hot Plug slots in a network from a single management station. Compaq designed PCI Hot Plug technology with ease of management as a primary consideration.

As illustrated in Figure 1, the Remote Monitor service is central to the operation of PCI Hot Plug technology. The Remote Monitor service acts as the connection point for all hot-plug communications. By using the Remote Monitor service as the primary interface, Compaq delivers true PCI Hot Plug capability without requiring hot-plug support directly in the OS.

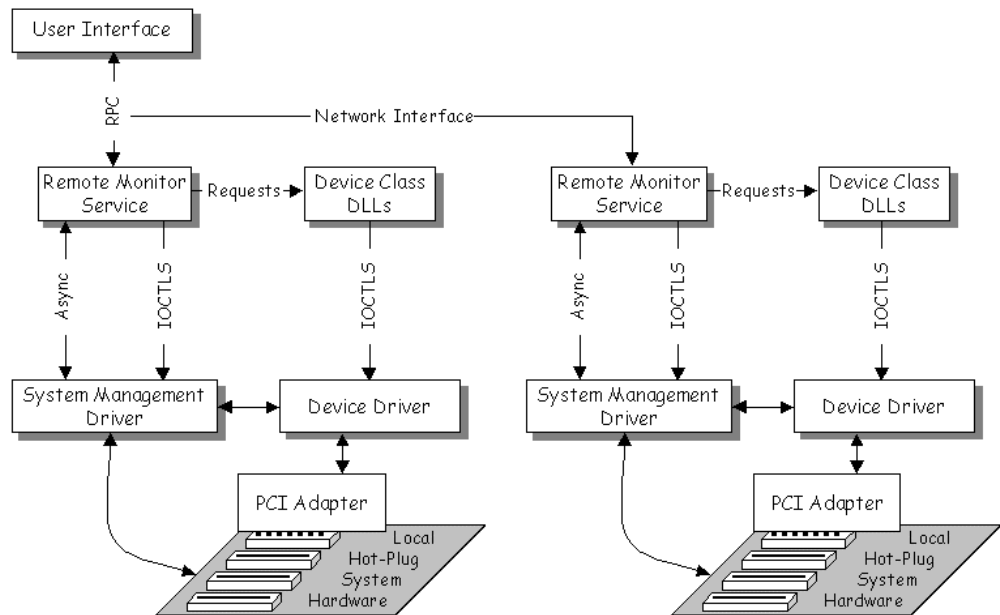


Figure 1: Overview of PCI Hot Plug Technology for the Windows NT Server 4.0 OS

When the user invokes a hot-plug function from the PCI Hot Plug Utility (Figure 2), the Remote Monitor service receives the request and routes it to the appropriate driver. For example, if the request involves action on a hot-plug slot, the Remote Monitor service routes the request to the System Management driver. The PCI Hot Plug Utility receives reports of the success or failure of the request by way of the Remote Monitor service as well.

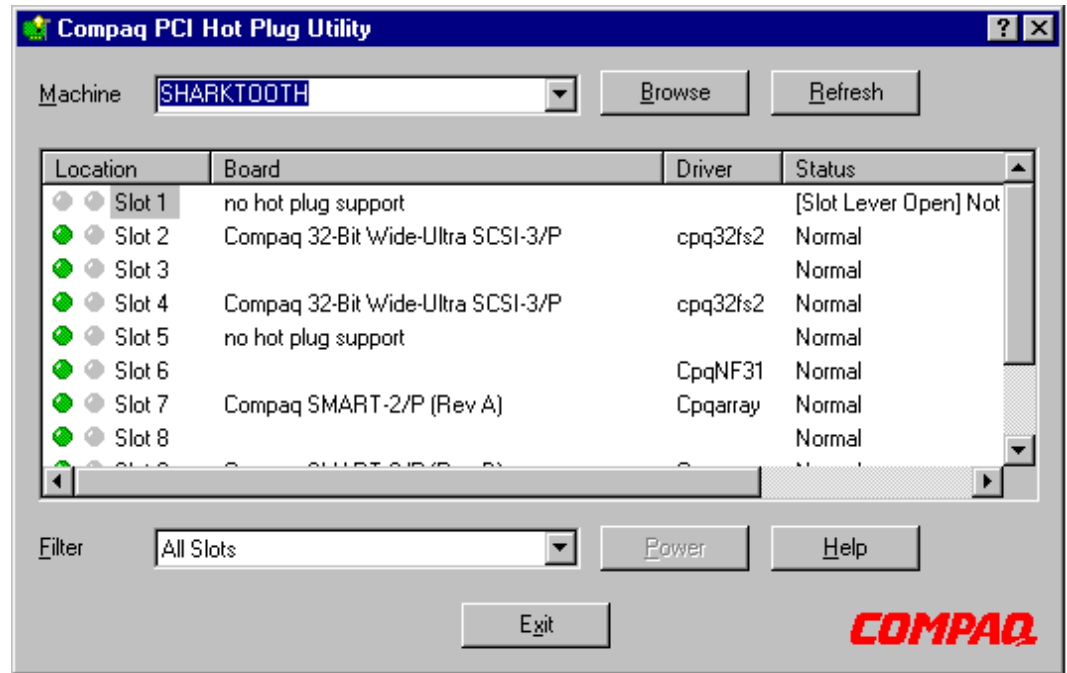


Figure 2: Compaq PCI Hot Plug Utility for the Windows NT Server 4.0 OS

If the request coming to the Remote Monitor service involves direct action to the controller in the hot-plug slot, the Remote Monitor service routes that request to the device-class dynamic link library (DLL) that supports the controller. These device-class DLLs communicate directly with the device drivers, which in turn manage the functions of the PCI controllers. Status reports of these events flow back to the PCI Hot Plug Utility by way of the Remote Monitor service.

By default, the Remote Monitor service starts automatically at system startup. Without the Remote Monitor service running, there is no hot-plug functionality.

Typical Scenario

In a typical scenario without push buttons in which the administrator replaces an adapter in a system with the Windows NT Server 4.0 OS, the following steps occur while the system is running:

1. The administrator invokes the PCI Hot Plug Utility.
2. Using the PCI Hot Plug Utility, the administrator highlights the slot occupied by the controller to be replaced.
3. The administrator clicks the *Power* button in the PCI Hot Plug Utility to remove power from the PCI Hot Plug slot.
4. The green LED for that slot will turn off, indicating that power is no longer applied to that slot.
5. The administrator opens the slot release lever.

6. The administrator removes the adapter.
7. The administrator inserts the replacement adapter of the same device type and revision as the adapter being replaced.
8. Before closing the slot release lever, the administrator attaches any cables to the adapter.
9. The administrator closes the slot release lever.
10. Using the PCI Hot Plug Utility, the administrator clicks the *Power* button to restore power to the slot.

Windows 2000 Server Operating System

To deliver a robust PCI Hot Plug solution for the Windows 2000 Server OS, Compaq developed a feature-rich software driver that heavily leverages the Plug and Play features in the Windows 2000 Server OS. The driver is the enabling piece and all other components are native to the Microsoft OS. For instance, the solution is integrated into the native user interface support in the Windows 2000 Server OS. Compaq's PCI Hot Plug solution is fully integrated into the following Windows 2000 Server OS administrative tools:

- Device Manager – provides user with information about how hardware is installed and configured and how it interacts with applications
- Hot Plug Device Tray Applet – provides user with a graphical view of hardware that can be unplugged or ejected
- Hardware Wizard (Figure 3) – assists user to install, uninstall, repair, unplug, eject, and configure hardware



Figure 3: Windows 2000 Server OS Hardware Wizard (from a beta version)

Compaq PCI Hot Plug Driver

Figure 4 illustrates the architecture of Compaq’s solution and how it integrates with the Windows 2000 Server OS. It shows core pieces of the Windows 2000 Server OS and Plug and Play architecture. Compaq’s PCI Hot Plug driver implements a layer of functionality that notifies Windows 2000 Server OS kernel components when hot-plug events occur. This layer also controls the PCI Hot Plug hardware and the hot-plug slots in response to control requests from the Windows 2000 Server OS administrative tools.

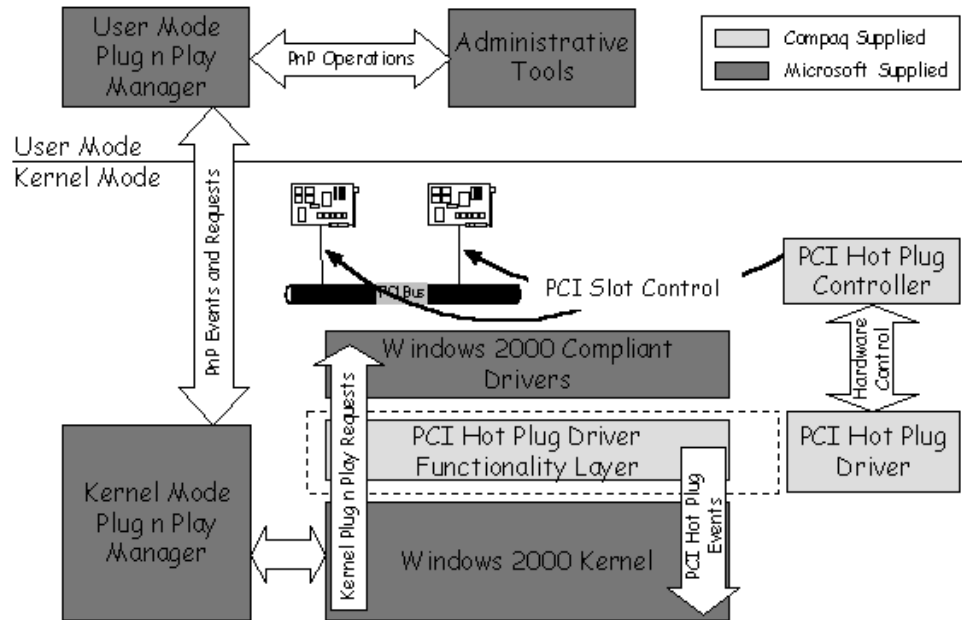


Figure 4: Overview of PCI Hot Plug Architecture for the Windows 2000 Server OS

This architecture eliminates the need to change any of the Windows 2000 Server OS core Plug and Play pieces and takes advantage of the Plug and Play support to implement PCI Hot Plug events. It also allows users to maintain identical functionality in Compaq’s PCI Hot Plug driver implementation and Microsoft’s follow-on ACPI implementation. The driver is dependent on the Windows 2000 Server OS architecture and will not run on previous versions of the OS.

To further drive the market adoption of PCI Hot Plug technology as industry standard, Compaq licensed its PCI Hot Plug technology to Intel. As a result, Compaq and Microsoft are positioned as the industry leaders in the PCI Hot Plug technology arena. Compaq’s PCI Hot Plug driver for the Windows 2000 Server OS takes hot-plug functionality a step further by allowing even mission critical databases and enterprise resource planning applications to maintain availability throughout a PCI Hot Plug event.

Device Drivers

Hot-plug-aware device drivers enable the system to control specific PCI adapters. Microsoft requires that independent hardware vendors add Plug and Play support to adapter drivers for the Windows 2000 Server OS. Compaq’s PCI Hot Plug solution will support any Windows 2000 Server OS compliant drivers—no additional changes are required to support hot replacement, hot upgrade, or hot expansion.

Typical Scenario

In a typical Windows 2000 Server OS scenario in which the administrator adds an adapter to an empty slot, the following steps occur while the system is running:

1. The administrator prepares the slot for installation of the adapter by opening the appropriate slot release lever and removing the expansion slot cover.
2. The administrator installs the adapter into the appropriate expansion slot.
3. The administrator closes the slot release lever.
4. The administrator uses the PCI Hot Plug Button to notify the Windows 2000 Server OS that power can be applied to the slot. The green LED will flash while the PCI Hot Plug driver, in conjunction with the Windows 2000 Server OS, performs the power state change.
5. The Windows 2000 Server OS will turn on power to the slot and automatically locate and load the appropriate device driver.

CONCLUSION

As PCI Hot Plug technology becomes more prevalent in the enterprise, Compaq continually raises the standard in high-availability and fault-tolerant solutions. PCI Hot Plug offers unprecedented server availability by allowing users to replace, upgrade, and add PCI adapters to the PCI local bus without powering down the server. Now, Compaq has not only developed an industry-leading hardware implementation for PCI Hot Plug but has also developed software solutions to deliver PCI Hot Plug functionality to Windows NT Server 4.0 and Windows 2000 Server network OS users.

Microsoft is a leading OS developer whose Windows technology is perfectly suited for integration of PCI Hot Plug capabilities. Compaq has worked closely with Microsoft to develop hot-plug capabilities for Windows network OS platforms.

PCI Hot Plug technology brings significant advances to the other high-availability solutions Compaq currently offers. By bringing this technology to the market as an open, industry standard, Compaq continues to strengthen its position as a leader in enterprise computing.