TECHNOLOGY BRIEF

June 1998

Compaq Computer Corporation

ECG Technology Communications

CONTENTS

PCI Hot Plug Technology

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.

This technology brief summarizes the PCI Hot Plug technology and describes Compaq's strategy for developing and standardizing this technology.

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

COMPAQ

NOTICE

PCI Hot Plug Technology
Fourth Edition (June 1998)
ECG080/0698

INTRODUCTION

Customers today need high-availability solutions that minimize or eliminate downtime. PCI Hot Plug technology allows a PCI adapter to be added, upgraded, or replaced while the host system is running and while other adapters in the system provide uninterrupted service. PCI Hot Plug technology adds to other high-availability solutions presently available from Compaq such as Recovery Server Options, Redundant Netelligent Network Interface Controllers (NICs), hot-pluggable power supplies, hot-pluggable fans, and hot-pluggable SCSI drives.

Three PCI Hot Plug Capabilities

PCI Hot Plug technology provides for three major capabilities: hot replacement, hot upgrade, and hot expansion.

Hot replacement is the process of removing a failed or failing PCI adapter and inserting an *identical* adapter into the same slot while the server is operating.

Hot upgrade is the process of replacing an existing adapter with an *upgraded* adapter or replacing the adapter's device driver with an upgraded device driver while the server is operating.

Hot expansion is the process of installing an *additional* adapter into a previously empty slot while the server is operating.

Synergistic High-Availability Techniques

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 redundant controller configurations, such as Compaq Redundant Netelligent NIC technology.

Compaq Redundant Netelligent NIC technology allows two similar NICs to share a single instance of device driver code. One NIC becomes the active network controller, and the other NIC acts as a standby controller. If the active NIC fails, the network traffic can be switched automatically to the standby NIC. With PCI Hot Plug, the failed NIC can be replaced without shutting down the system. Thus, the end user can have continuous service and the administrator can eliminate both planned and unplanned downtime.

PCI HOT PLUG: COMPAQ STRATEGY

Compaq's decision to develop PCI Hot Plug technology is focused on addressing a key customer issue: as computing environments grow more complex, the business costs of unplanned system downtime are soaring. The increasing cost of unplanned downtime in business-critical environments, compounded by the time spent tracking the source of network or component failures, is creating a greater need for high-availability solutions like PCI Hot Plug.

In the past, reliable and powerful around-the-clock performance was available only from expensive, proprietary systems. Although these proprietary solutions may give the developer an initial competitive advantage, they generally have not been well received by customers. Proprietary solutions tend to be more costly and less accessible. They also require the customer to be wary of compatibility issues.

An open, industry-standard approach, such as Compaq's PCI Hot Plug effort, has multiple benefits. First, customers benefit from the increased availability of the hot-plug solution. Because PCI Hot Plug is an open, industry standard, it allows multiple system providers, operating system (OS) developers, and adapter suppliers to implement PCI Hot Plug solutions. Additionally, customers have investment protection because hot plug is compatible with previous PCI standards. Therefore, any new hot-plug system hardware, OSs, or adapter device drivers are PCI compliant and will work with existing PCI-compliant systems. The entire system does not

need to be overhauled just because certain components are hot-plug capable. The technology is fully backward compatible.

These same factors are also benefits when viewed from an industry perspective. For example, as an industry-wide standard, PCI Hot Plug technology is functional with multiple OSs, hardware systems, and adapters. This interoperability gives the industry a strong footing to ensure adoption of the technology and progress to other advancements. Because of the focused effort on a single standard, resources are not fragmented into modifying solutions for particular proprietary hardware or software but provide synergistic growth into more advanced technologies. As an open standard, PCI Hot Plug is attractive to the major OS and independent hardware vendors (IHVs) and encourages their development of compliant products.

An open, industry standard clearly benefits Compaq as well. By developing PCI Hot Plug technology and initiating the industry standard for hot plug, Compaq extends its technology leadership position in the industry. Compaq will also benefit from the interoperability of the open standard, as it will provide a natural progression into further high-availability advancements. With the ProLiant 6500 and ProLiant 7000 servers, Compaq delivered the first industry-standard PCI Hot Plug systems and once again set the standard in high-availability and fault-tolerant solutions for the distributed enterprise.

PROGRESS TOWARD AN INDUSTRY STANDARD

Since Compaq's June 1996 announcement to deliver PCI Hot Plug technology as an open, industry standard, Compaq has worked with key hardware and software partners and the industry-wide PCI standards committee. This effort allows customers to move forward in implementing this technology with greater flexibility. Compaq has taken several steps to ensure broad industry acceptance of the technology, including:

- Standardized PCI Hot Plug technology by initiating and chairing the PCI Special Interest Group (SIG) Hot Plug Workgroup. The workgroup included other industry leaders such as Adaptec, Inc.; Cirrus Logic, Inc.; Digital Equipment Corporation; Hewlett-Packard Company; IBM Corporation; Intel; Microsoft; Novell; Pro-Log Corporation; The Santa Cruz Operation, Inc. (SCO); and Texas Instruments Incorporated. Efforts of the workgroup allowed a quick release of the PCI Hot Plug Specification—only 14 months from the group's charter. For more information on the PCI Hot Plug Specification, visit the PCI SIG website at http://www.pcisig.com.
- Partnered with OS developers to ensure incorporation of the PCI Hot Plug standard in product releases. Compaq has taken a proactive role in ensuring broad OS support for hot-plug capabilities. Actions to date range from the development of cross-company design teams to the delivery of PCI Hot Plug platforms for testing OSs. Currently, Microsoft, Novell, and SCO support PCI Hot Plug.
- Worked with leading adapter vendors such as 3Com Corporation; Adaptec; Dialogic Corporation; Digi International; Mylex Corporation; QLogic Corporation; American Megatrends, Inc. (AMI); Madge Networks; SMC Networks Inc.; and SysKonnect to ensure broad acceptance and rapid implementation of the standard.
- Licensed PCI Hot Plug technology to be available in Intel architecture-based server platforms. Intel will incorporate Compaq's implementation of PCI Hot Plug, including the hot-plug controller and related system technologies, in future products.
- Developed hot-plug aware drivers for Compaq NetFlex controllers, Netelligent controllers, Smart array controllers, and Fast-Wide SCSI-2 controllers.

- Developed the Compaq ProLiant 6500 and ProLiant 7000, announced in August 1997, as the first available server platforms conforming to the PCI Hot Plug Specification and added next-generation PCI Hot Plug features to Pentium II Xeon Models of the ProLiant 7000 announced in June 1998.

Compaq is in a unique position to lead this standardization effort. Not only is Compaq a pioneer in the development of systems hardware, but Compaq also has extensive experience in systems configuration software and device driver development. Because of its unique position, Compaq has been able to gather the support of major software developers and IHVs to deliver PCI Hot Plug technology as an open, industry standard.

SUMMARY OF PCI HOT PLUG

Taking a very general approach, a fully capable hot-plug system includes the hot-plug system hardware, hot-plug aware software and OS support, hot-plug capable device drivers, and a hot-plug aware user interface, as shown in Figure 1. The hardware and software work together to ensure that any hot-plug activity occurring on the PCI bus is benign to other devices on the PCI bus.

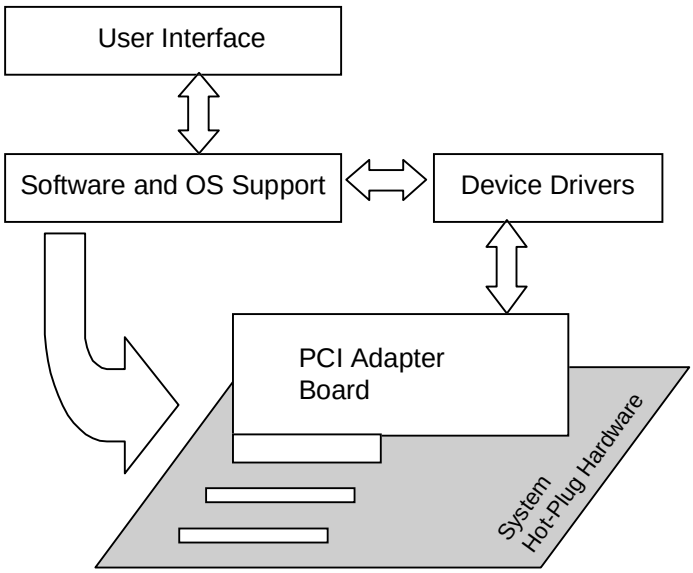

Figure 1: Generic PCI Hot Plug Technology

System Hardware

It is important to note that while the PCI Hot Plug Specification identifies the technical requirements of a hot-plug capable system, it does not specify the implementation of this technology. 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. Compaq designed its hot-plug controller to manage the following components:

- **PCI Bus.** The 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 latest PCI Hot Plug servers. The button is pressed to signal the software to initiate a power state change. While the button is more convenient, the same functionality is provided through the software interface. Each slot has its own button to indicate which slot is to be addressed by the supporting software.

System Chassis Design

In addition to the electrical components, the overall system design (system chassis and other hardware) has been adapted for safety and ease of adapter installation and removal. Chassis design changes include quick-release latches on the adapter slots to allow fast and easy removal and insertion of adapters; wider slot spacing and flexible slot separators to allow users to remove and insert adapters without electrically contacting (shorting) other components; and a top access shield that allows users access to adapters yet prevents access to other internal components. These design changes meet or exceed all regulatory safety standards.

System Software

PCI Hot Plug technology is supported by Microsoft, Novell, and SCO. While Compaq has worked to ensure that each OS is compatible with the PCI requirements, user interface applications may vary from one OS to another since each user interface is optimized for that OS. Each OS supplier has defined interface layers between the hot-plug hardware and the OS kernel to support PCI Hot Plug technology.

Hardware and Software Control

In a typical 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 or the software user interface to notify the OS that power can be applied to the slot. The green LED flashes while the OS performs the power state change.
5. The OS turns on power to the slot and either automatically locates and loads the appropriate device driver or prompts the administrator to locate and load the driver.

Adapters and Device Drivers

Most industry-standard PCI adapters can be used without any modifications. For industry-standard PCI adapters to have hot-plug functionality, however, new features must be added to the device drivers.

Leading IHVs committed to modifying their device drivers to be hot-plug aware include 3Com, Adaptec, Dialogic, Digi International, Mylex, QLogic, AMI, Madge, SMC, and SysKonnect. The standardization work with the PCI SIG has encouraged the proliferation of hot-plug aware drivers for third-party devices. In addition, Compaq has developed hot-plug capable drivers for its own leading PCI server adapters.

Compatibility Issues

PCI Hot Plug technology addresses compatibility concerns by using standard PCI adapters. A hot-plug system requires a hot-plug platform, a hot-plug OS, and hot-plug adapter drivers. A system can include any combination of hot-plug and conventional versions of each of these components, including a mix of both hot-plug and conventional adapter drivers. However, a particular adapter can be hot-plugged only if all three components for that adapter support hot-plug operation.

A hot-plug platform supports loading a conventional OS. The system behaves as a conventional system if no hot-plug software is loaded. Hot-plug OSs are designed to load and execute on any platform. If no hot-plug controller is found on the platform, then the OS will not permit the user to perform any hot-plug operations at the user interface.

Hot-plug OSs generally require driver modifications to support full hot-plug capability. However, as with any driver revision, the OS will often support previous generations of drivers. Furthermore, in some cases, the new driver can be loaded onto the previous version of the OS. If a conventional driver is loaded onto a hot-plug OS, or vice versa, the driver will continue to have the same capability it always had in the conventional application. However, the adapter cannot be hot-plugged unless both the driver and the OS support the hot-plug operation.

CONCLUSION

With the introduction of PCI Hot Plug technology, Compaq once again set the standard in high-availability and fault-tolerant solutions for the enterprise. 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. With the release of the ProLiant 6500 and ProLiant 7000, Compaq made the chassis and electronics design changes required for safe and efficient removal and insertion of PCI adapters without powering down the server. Next-generation PCI Hot Plug features are included in Compaq's newest enterprise server, the Pentium II Xeon Model of the ProLiant 7000, released in June 1998.

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.