New Challenges Drive Compaq Advanced Memory Protection Strategy

Abstract:
Compaq is raising the bar and moving further in the enterprise space with Advanced Memory Protection technologies that will improve the fault tolerance of industry-standard servers. Businesses are becoming more dependent on these servers to run memory-intensive applications. This trend is driving operating systems to support more memory and pushing the memory capacity of servers to new levels. Consequently, as storage densities of memory components and server memory capacities increase to meet the demand, the likelihood of memory errors also increases. Memory errors can corrupt data and cause servers to crash, resulting in the permanent loss of business data and lost revenue from downtime.

Compaq established its leadership in memory protection in 1993 with the introduction of Error Checking and Correcting (ECC) memory in industry-standard servers and in 1996 by developing Advanced ECC technology. In the next generation of Compaq ProLiant servers, Compaq will offer three levels of Advanced Memory Protection that provide increased fault tolerance for applications requiring higher levels of availability: Online Spare Memory, Hot Plug Mirrored Memory, and Hot Plug RAID Memory. All three levels will maintain server availability and memory reliability without service intervention. Online Spare Memory will be beneficial to customers with sites that cannot afford downtime from memory errors, yet can wait until a scheduled downtime to replace failed memory modules. Hot Plug Mirrored Memory will allow failed memory modules to be replaced without shutting down the server. Compaq Hot Plug RAID Memory will deliver the highest level of server availability, providing hot-replace, hot-add, and hot-upgrade capability.
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New Challenges Drive Compaq Advanced Memory Protection Strategy
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Introduction

We all have heard of highly publicized server crashes that cause Internet customers to click elsewhere and e-Business' stock prices to plummet. Less publicized, but nonetheless feared, are the effects of data corruption. Both events can be caused by memory errors. What most of us don’t realize is that if it were not for memory protection technologies, more data corruption and crashes would occur. It’s ironic that the effectiveness of memory protection technologies have caused us to believe that memory reliability is no big deal, that is, until something goes wrong. When a memory-related crash does occur, the cause is often unclear. Because there is no time to determine which memory component failed, the problem is often solved by replacing all the memory modules in a server. Memory modules are abundant and little thought is given to replacing all of them to get a server back up and running as quickly as possible. The real cost, however, is in lost productivity and, depending on the application, lost revenue.

System memory has become more reliable over the years because of better manufacturing processes and memory protection technologies like those developed by Compaq. Compaq has now turned its attention to the next memory reliability challenge—the probability that memory errors will increase as the density and number of memory devices in servers increase.

To meet this challenge, Compaq will offer three levels of Advanced Memory Protection: Online Spare Memory, Hot Plug Mirrored Memory, and Compaq Hot Plug RAID Memory.

What’s Driving Memory Requirements?

Increasingly, businesses and consumers are using the Internet as a common source of commerce, information, and entertainment. Fueled by these factors, Internet traffic is doubling every 6 months. Software vendors are developing more complex and memory-intensive applications to feed the insatiable hunger of the telecommunications, financial, and entertainment industries. As a result, operating system vendors are increasing the amount of memory that operating systems can address [see adjacent chart].

Compaq and other server manufacturers are responding by packaging faster processors and more memory in modular chassis that allow eBusinesses to maximize computing power in crowded data centers. For example, today’s Compaq ProLiant servers contain processors operating at up to 2-GHz and support up to 32 GB of memory. And the next generation of Compaq ProLiant servers will support up to 64 GB of system memory [see adjacent chart]. Consequently, as memory capacity increases with each new generation of servers, so does the possibility of memory errors. But what are the real causes of memory errors and why are they expected to increase in the future?

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The Causes of Memory Errors

A dynamic random access memory (DRAM) chip is an electronic storage device that contains millions of memory cells; each cell contains an extremely small capacitor. DRAM stores a “1” data bit in a cell by electrically charging its capacitor. An uncharged capacitor contains a “0” data bit. The level of the electrical charge is determined by the operating voltage of the memory device. When a memory cell is accessed during a read operation, the capacitor’s voltage determines whether it is read as a “1” or “0” bit.

Until recently, industry-standard memory components operated at 5 volts. However, because of improvements in DRAM storage density (smaller and more sensitive cells), the operating voltage was decreased to 3.3 volts and then to 2.5 volts to allow memory to run faster and consume less power. Because memory storage density is increasing and operating voltage is shrinking, there is a higher probability that data in memory cells can be inadvertently changed. And whenever a data bit is misinterpreted and not corrected, the error can cause an application to crash or cause it to pass on bad data. For example, a decimal point on a check can show up three digits in the wrong direction!

All memory storage devices are inherently susceptible to memory errors. Memory errors generally fall into two categories—hard errors and soft errors. A hard error consistently returns incorrect results, indicating that part of a memory device is broken or defective. For example, a memory cell may be stuck so that it always returns “0” bit, even when a “1” bit is written to it.

Soft errors are more prevalent than hard errors. Today’s servers with large memory capacities will experience several soft memory errors annually. Soft errors occur randomly when an electrical disturbance near a memory cell alters the charge on the capacitor. A soft error does not indicate a problem with a memory device because once the data is corrected, the same error does not reoccur. Scientific research has revealed that the causes of most soft errors are literally “out of this world” (see “Cosmic Particles” at right).

There are two ways to protect against memory errors: testing and the use of error detection/correction technologies. Compaq minimizes the occurrence of most manufacturing-related memory errors by certifying memory manufacturers and continuously testing their memory products. However, soft errors cannot be prevented by these means. As memory manufacturers increase the capacity of memory devices, the likelihood of soft memory errors likewise increases. This is why error detection and correction technologies are so important. Without them, business-critical applications would sporadically crash without warning.

Error Prevention Starts with Highly Reliable Memory

As memory chips become faster and more complex, testing them becomes more difficult and expensive. Memory device manufacturers invest heavily in testing systems, and they continually revamp their testing procedures to maintain device quality. Due to the constant changes in manufacturing processes, Compaq qualifies each memory module design and manufacturing process to prevent the occurrence of hard errors. In addition to the rigorous qualification of module manufacturers, Compaq further tests every memory module in the model of server that it will be installed. This process includes testing each manufacturer's

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2 Soft error rate is based on 460 soft errors per year for 10,000 computers with 64 MB of memory each. This is approximately 3 soft errors per computer per year for every 4 GB of memory.
modules on every model of Compaq servers currently shipping and re-qualifying every module manufacturer each time Compaq offers a new processor speed or a new server platform. This testing and re-qualification process results in continuous improvement of memory module reliability.

Superior qualification and testing procedures allow Compaq to offer a three-year pre-failure warranty on Compaq memory. The Compaq Pre-Failure Warranty allows for replacement of any Compaq dual in-line memory module (DIMM) that exceeds predefined limits for correctable errors. These errors are recorded by the server and can be verified through Compaq Insight Manager or by running a diagnostics program.

Compaq Innovation Leads the Industry in Memory Protection

Despite the measures to prevent hard errors, memory failures still occur from problems not directly related to memory. For servers running business-critical applications, these memory failures can cause servers to crash and result in the permanent loss of business data. ECC technology, introduced in industry-standard servers by Compaq in 1993, has provided adequate protection for many applications. However, as shown in the upper chart, the effectiveness of ECC protection decreases (server outages increase from 3% to 48%) as memory capacity rises. This fact is significant because two factors are driving industry-standard servers to support more memory capacity—operating systems now support greater amounts of memory and low-cost, high-capacity memory modules are more available.

To improve memory protection, Compaq introduced Advanced ECC technology in 1996. Compaq and other server manufacturers continue to use this solution in current product lines. Standard ECC devices can correct a single-bit error during a read from a DIMM. Advanced ECC can correct a multi-bit error that occurs within one DRAM chip and thus can correct a complete DRAM chip failure. Although Advanced ECC provides failure protection, it can reliably correct multi-bit errors only when they occur within a single DRAM chip and it does not provide failover or hot-plug capability. In the next generation of Compaq ProLiant servers, Compaq will offer three levels of Advanced Memory Protection that provide increased fault tolerance for applications requiring higher levels of availability.

Compaq’s next generation of industry-standard servers will approach levels of fault tolerance and availability that were once the domain of mainframe servers [see bottom chart]. The Compaq ProLiant 300, 500, and 700 Series servers will feature one or more Advanced Memory Protection technologies including Online Spare Memory, Hot Plug Mirrored Memory, and Hot Plug RAID Memory.

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3 For more information, please read Why Buy Compaq Memory?, document number 13KH-1100A-WWEN.
4 Certain conditions exist. Compaq Insight Manager must be used for Pre-Failure Warranty. For more information, please read Why Buy Compaq Memory?, document number 13KH-1100A-WWEN.
Online Spare Memory

Online Spare Memory is beneficial to businesses with sites that do not have sufficient IT staff available to service a failure, do not always have replacement memory on hand, or where the server cannot be brought down before a scheduled shutdown. Customers will be able to designate one memory bank as Online Spare Memory and designate the remaining banks as system memory. Each memory bank will contain two industry-standard DIMMs. The Online Spare Memory bank copies whichever memory bank reaches its pre-defined error threshold. This maintains server availability and memory reliability without service intervention. The DIMM that exceeded the error threshold can be replaced at the customer's convenience during a scheduled shutdown. Online Spare Memory offers a higher level of memory protection than Advanced ECC alone.

Hot Plug Mirrored Memory

Hot Plug Mirrored Memory is a fault-tolerant memory option that provides a higher level of availability than Online Spare Memory. If a memory module has achieved its pre-defined threshold of correctable memory errors, its chance of encountering a multiple bit error increases dramatically and the server operates at a higher risk of failure until the degraded memory is replaced. For this reason, Hot Plug Mirrored Memory is beneficial to businesses that cannot afford downtime and cannot risk waiting until scheduled downtime to replace degraded memory modules. When a server is in Hot Plug Mirrored Memory mode, data is written to two groups of industry-standard DIMMs. Data is read from one group of DIMMs while the other group contains a mirrored copy of the data. For this reason, the two groups must be configured identically. If a read error is encountered in a DIMM, or if the DIMM reaches a pre-failure warranty condition, the data is read from its mirrored DIMM. This allows the customer to hot replace the failed DIMM without shutting down the server, thus improving availability. Compaq uses Hot Plug Mirrored Memory in conjunction with Advanced ECC to provide protection against all ECC-detectable errors except the highly unlikely case of an error in exactly the same location on a DIMM and its mirrored DIMM.

Compaq Hot Plug RAID Memory

Compaq Hot Plug RAID Memory delivers unprecedented levels of availability, scalability, and fault tolerance for 24x7 applications. It allows the memory subsystem to operate continuously, even in the event of a complete memory device failure. RAID, in this case, stands for Redundant Array of Industry-standard DIMMs. Servers with Compaq Hot Plug RAID Memory use five memory controllers to control five memory cartridges, each cartridge can hold up to eight industry-standard DIMMs. When the memory controllers need to write data to memory, they split the data into four blocks and write them to four of the memory cartridges. A RAID engine calculates parity information, which is stored on the fifth cartridge. With the four data cartridges and the parity cartridge, the data subsystem is completely redundant such that if the data from any DIMM is incorrect or any cartridge is removed, the data can be recreated from the remaining four cartridges.

The redundancy in Compaq Hot Plug RAID Memory allows customers to hot-replace, hot-add, and hot-upgrade DIMMs without shutting down the server. When a hot-plug operation is completed, Compaq Hot Plug RAID Memory automatically rebuilds the data across all the memory cartridges. Servers will have hot-replace capability directly out of the box, regardless of the operating system used. Hot-add and hot-upgrade capability allows customers to scale the server's available memory by adding DIMMs. Hot-add and hot-upgrade require support from the operating system to recognize the additional memory that is available. Microsoft Windows® Advanced Server, Windows® Data Center, Novell NetWare 6.0, and SCO UnixWare 7.1.2 will support these capabilities in the Compaq ProLiant 700 Series servers. Compaq is working with other operating system vendors to ensure that these capabilities will be supported in their future releases.
What does all this mean? For customers who deploy industry-standard servers with large memory systems to run highly available applications, Compaq's Advanced Memory Protection technologies will provide the best memory protection available. As shown in the adjacent chart, even with the major increase in memory capacity per server, Compaq's Advanced Memory Protection technologies will provide the same minimal rate of memory-related failures as ECC does in smaller memory systems. Compaq Hot Plug RAID Memory will provide the highest level of availability for industry-standard servers with large memory systems to run 24x7 applications.

The table below provides an interline comparison and competitive advantage of Compaq Advanced Memory Protection technologies to Advanced ECC and IBM Chipkill Protect Memory [see What is Chipkill?]. All technologies shown provide device failure protection. As of release of this paper, IBM Chipkill Protect Memory does not provide hot-plug capabilities. Compaq Hot Plug Mirrored Memory will provide hot-replace capability while Compaq Hot Plug RAID Memory will provide hot-replace, hot-add, and hot-upgrade capabilities. Note that Hot Plug RAID Memory will provide the most cost effective memory protection—the expense for additional memory is 25 per cent of Compaq Hot Plug Mirrored Memory.

### Advanced Memory Protection - Interline Comparison and Competitive Advantage

<table>
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<tr>
<th></th>
<th>IBM Chipkill Memory</th>
<th>Compaq Advanced ECC Technology</th>
<th>Compaq Online Spare Memory</th>
<th>Compaq Hot Plug Mirrored Memory</th>
<th>Compaq Hot Plug RAID Memory</th>
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<td>10%-50%</td>
<td>100%</td>
<td>25%</td>
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**What is Chipkill?**

Chipkill Protect Memory is a term trademarked by IBM to describe memory device failure protection. Initially, Chipkill Protect technology used a proprietary application-specific integrated circuit (ASIC) placed on a DIMM to provide memory protection. Adding an ASIC to the DIMM also increased the base cost of Chipkill Protect DIMMs. Lack of competition and low production volumes increased the cost of these proprietary DIMMs as well. Also, no hot-plug capabilities are inherent in Chipkill Protect Memory. Now, IBM has changed its Chipkill Protect technology to refer to an advanced ECC technique that is implemented in the chipset rather than the DIMM. This is equivalent to Compaq's Advanced ECC implementation.
Summary

The demand for servers with more memory capacity is unrelenting—driven by the increasing use of the Internet in the telecommunications, financial, and entertainment industries. The Internet's role will continue to expand in all industries, forcing corporations and service providers to scale computing power in crowded data centers. Technologies are constantly changing as server manufacturers respond by packaging faster processors and more memory in modular chassis that allow eBusinesses to quickly scale computing resources. These unstoppable forces will overwhelm many IT organizations because businesses are beginning to downsize IT staff to cut costs. In this environment, servers must become more fault tolerant to reduce downtime and lost revenue.

While meeting the demand for scalability, the challenge for server manufacturers is to maintain the reliability of the memory system, even though there is a higher probability of memory errors as memory densities and capacities climb. Compaq is meeting the challenge with three fault-tolerant memory protection technologies: Online Spare Memory, Hot Plug Mirrored Memory, and Hot Plug RAID Memory.

From the beginning, Compaq established itself as the innovative leader in memory protection, first by using standard ECC technology in industry-standard servers in 1993 and then by introducing Advanced ECC technology in 1996. Standard ECC devices can correct a single-bit error during a read from a DIMM. Advanced ECC technology is an innovative solution that can correct a multi-bit error that occurs within a single DRAM chip and thus can correct a complete DRAM chip failure. Compaq and other server manufacturers continue to use Advanced ECC in current product lines.

Soon, the next generation of Compaq servers will build on Advanced ECC by increasing fault tolerance. Online Spare Memory will be beneficial to customers with sites that cannot afford downtime from memory errors, yet can wait until a scheduled downtime to replace failed memory modules. Hot Plug Mirrored Memory will provide a more fault-tolerant option for sites that cannot afford downtime from memory errors and do not want to wait until scheduled downtime to replace failed memory modules. It will allow memory modules to be hot-replaced without shutting down the server. Compaq Hot Plug RAID Memory will provide the highest level of availability for customers who deploy industry-standard servers with large memory systems to run 24x7 applications. It will allow the memory subsystem to operate continuously, even in the event of a complete memory device failure. It will allow industry-standard DIMMs to be hot-replaced, hot-added, and hot-upgraded.

The bottom line for our customers is Compaq Advanced Memory Protection will enable them to chose a system with the level of memory availability they prefer, thus enhancing the robustness of their final solution.