



HP Advanced Memory Protection technologies

technology brief, 5th edition

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Abstract

This technology brief explains the causes of system memory errors and describes the methods that HP uses to prevent "hard" memory errors and to detect and correct inevitable "soft" errors. This document then describes the HP Advanced Memory Protection technologies that go beyond error correction to increase the fault tolerance of HP ProLiant ML and DL 300- and 500-series servers.

Introduction

Businesses are increasingly dependent on industry-standard servers to run memory-intensive and mission-critical applications. This trend is driving operating systems to support more memory and pushing the memory capacity of servers to new levels. System memory has become more reliable over the years because of better manufacturing processes and memory protection technologies like error checking and correcting or error correcting code (ECC). HP first introduced ECC and Advanced ECC in industry-standard servers. However, as memory component density and server memory capacity continue to increase, there is a higher probability of memory errors occurring. Memory errors can corrupt data and cause servers to crash, resulting in the permanent loss of business data and lost revenue from downtime.

To meet this memory reliability challenge, HP offers two levels of Advanced Memory Protection that provide increased fault tolerance for applications requiring higher levels of availability. HP customers can choose a system with the level of memory protection they prefer—Online Spare Memory or Mirrored Memory.

First, this paper explains the causes of memory errors and why the possibility of memory errors is increasing in servers. Then it describes the functions and limitations of established methods to prevent and detect most memory errors. Lastly, it summarizes the fault-tolerant Advanced Memory Protection technologies included in the HP ProLiant ML and DL 300- and 500-series servers.

While all ProLiant servers support Advanced ECC, the other Advanced Memory Protection feature sets discussed in this paper are currently found in ProLiant ML and DL 300- and 500-series servers. For information about Advanced Memory Protection capabilities of specific ProLiant servers, refer to the server's user guide.

Memory errors

Memory modules used in servers are electronic storage devices; therefore, they are inherently susceptible to memory errors. Computers generally use two types of system memory devices—static random access memory (SRAM) and dynamic RAM (DRAM). SRAM is used for cache memory because it is very fast and retains its data until the power is turned off. DRAM chips, which are used for main memory, are installed on 168-pin dual inline memory modules (DIMMs). Each DRAM chip stores data in columns and rows of capacitors (memory cells) that must be continuously recharged, or refreshed, to preserve the data. A charged capacitor represents a "1" data bit and an uncharged capacitor represents 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 charge determines whether it is read as a "1" or "0" data bit. For example, in a 1.8-volt system, a sensor reads a capacitor with a charge of +1.8 V as a "1" bit and a sensor reads a capacitor discharged to 0 V as a "0" bit. As long as the voltage is closer to +1.8 V than to 0 V, the sensor will read the value correctly. However, if a capacitor's charge is affected by some external event, the data may become incorrect. These memory errors can cause applications and operating systems to crash and can result in the permanent

loss of business data. Memory errors are classified by the number of bits that are affected—single-bit or multi-bit—and the cause of error.

Single-bit and multi-bit errors

The memory bus is a circuit that consists of two parts: the data bus and the address bus. The data bus is a set of traces that carry the actual data to and from SDRAM. Each trace carries one data bit at a given time. Today's computers have a 64-bit wide data bus, which means that the bus transports 64 bits at a time. These 64 bits constitute an ECC data word. An error in one bit of a data word is called a single-bit error. An error in more than one bit of a data word is called a multi-bit error.

Hard errors and soft errors

Memory errors are referred to as either hard errors or soft errors, depending on their cause. A hard error is caused by a broken or defective piece of hardware, so the device consistently returns incorrect results. For example, a memory cell may be stuck so that it always returns "0" bit, even when a "1" bit is written to it. Hard errors can be caused by DRAM defects, bad solder joints, connector issues, and other physical issues. Soft errors are more prevalent. They 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 stored data is corrected (for example, by a write to a memory cell) the same error does not recur.

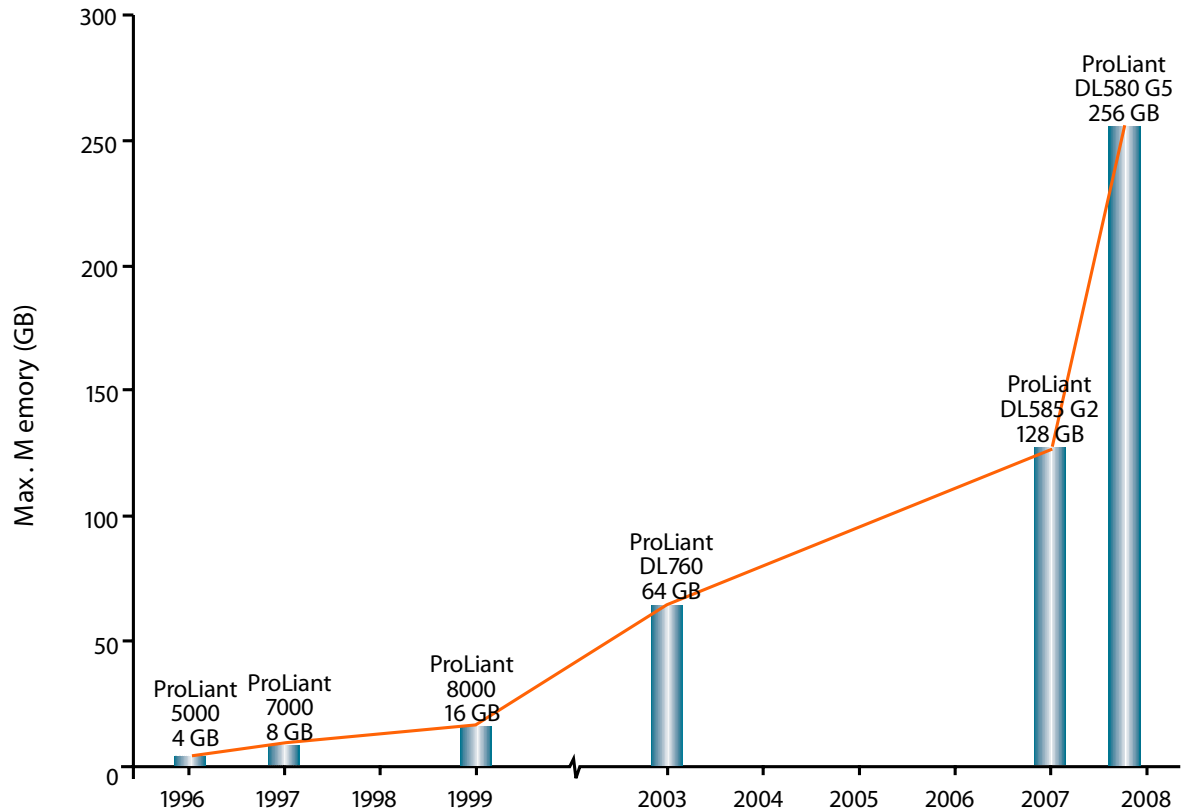
Increasing possibility of memory errors

Two trends are resulting in the increased likelihood of memory errors: the memory capacity of servers is expanding and the storage density of memory components is increasing.

Effect of memory capacity

Software vendors are developing increasingly complex and memory-intensive applications. This is driving operating systems to address more memory, which is causing manufacturers to expand the memory capacity of servers. For example, some HP ProLiant servers now support up to 256 GB of memory (Figure 1). As manufacturers continue to expand the memory capacity of servers, the possibility of memory errors likewise increases.

Figure 1. The memory capacity of HP ProLiant servers is growing to meet application demands.



Effect of SDRAM storage density and operating voltage

Two parameters of DRAM are inextricably tied together—the storage density of the DRAM chips and the operating voltage of the memory system. As the size of memory cells decreases, the DRAM storage density increases along with the memory cells' sensitivity to voltage. Initially, industry-standard DIMMs operated at 5 volts. However, because of improvements in DRAM storage density, the operating voltage was decreased to 3.3 V, 2.5 V, and then 1.8 V 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 an error may occur. Whenever a data bit is misinterpreted and not corrected, the error can cause an application to crash.

Methods to prevent memory errors

There are two ways to protect against memory errors: testing memory modules and using error detection/correction technologies. HP has long established its leadership in the qualification and testing of memory components and backs its testing procedures with a Pre-failure Warranty.

Memory testing

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, HP qualifies each memory module design and manufacturing process to minimize the occurrence of hard errors. In addition to the rigorous qualification processes of module manufacturers, HP further tests every memory module in the model of ProLiant server in which it will be installed. This process includes testing each manufacturer's modules on every model of HP ProLiant server currently shipping and re-qualifying every module manufacturer each time HP offers a new

processor speed or a new server platform.¹ This testing and re-qualification process results in continuous improvement in memory module reliability.

Superior qualification and testing procedures allow HP to offer a three-year Pre-failure Warranty on HP memory. The HP Pre-failure Warranty allows for replacement of any HP DIMM that exceeds predefined limits for correctable errors. These errors are recorded by the server and can be verified through HP Insight Manager or a diagnostics program.

HP Pre-failure Warranty

The Pre-failure Warranty, which is standard on all HP ProLiant servers, extends the advantage of an HP three-year, limited warranty on critical components, such as memory, before they actually fail. Specifically, the Pre-failure Warranty ensures that when customers receive notification from HP Systems Insight Manager that a critical server component may fail, the component is replaced free of charge under the warranty. With the Pre-failure Warranty, system administrators can proactively schedule downtime for maintenance and not interrupt critical business operations that rely on these enterprise servers.

During the warranty period, the Pre-failure Warranty covers the replacement of DIMMs used in a server's main memory when the predefined thresholds for correctable errors have been exceeded. The predefined thresholds can differ among system architectures.

Non-repeating, correctable soft errors are not covered under warranty since their occurrence requires no action.

Error detection/correction technologies

HP 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. The only true protection from memory errors is to use some sort of memory detection or correction protocol. Some protocols can only detect errors, while others can both detect and correct memory problems, seamlessly.

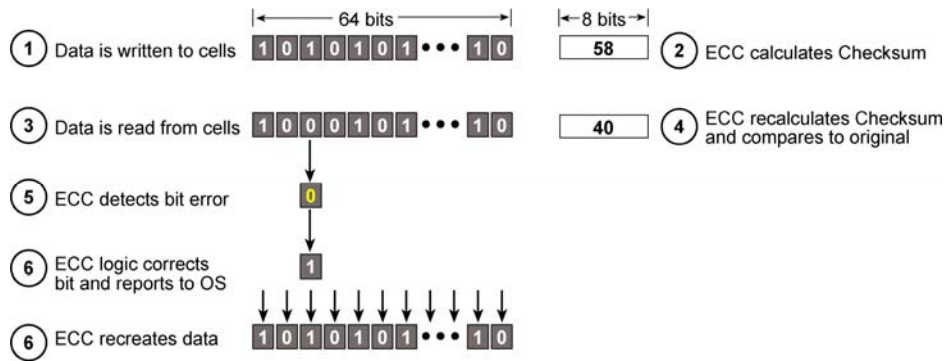
ECC memory

In 1993, HP was the first company to introduce ECC memory in industry-standard servers. This significantly reduced the probability of fatal memory failures. ECC memory is now standard in all HP ProLiant servers. ECC provides added protection over parity checking. Parity checking provides single-bit error detection, but it does not correct memory errors or handle multi-bit errors. ECC detects both single-bit and multi-bit errors in a 64-bit data word, and it corrects single-bit errors.

ECC encodes information in a block of 8 bits to permit the recovery of a single-bit error. Every time data is written to memory, ECC uses a special algorithm to generate values called check bits. The algorithm adds the check bits together to calculate a checksum, which it stores with the data. When data is read from memory, the algorithm recalculates the checksum and compares it with the checksum of the written data. If the checksums are equal, then the data is valid and operation continues. If they are different, the data has an error and the ECC memory logic isolates the error and reports it to the system. In the case of a single-bit error, the ECC memory logic can correct the error and output the corrected data so that the system continues to operate (Figure 2).

¹ For more information, download the white paper *Why Buy HP Memory?*, at <http://h71028.www7.hp.com/ERC/downloads/4AA0-4216ENW.pdf>.

Figure 2. The diagram displays ECC logic locating and correcting a single-bit error.



In addition to detecting and correcting single-bit errors, ECC will detect (but not correct) errors of two random bits and up to four bits within a single DRAM chip. ECC memory handles these multi-bit errors by generating a non-maskable interrupt (NMI) that instructs the system to halt to avoid data corruption.

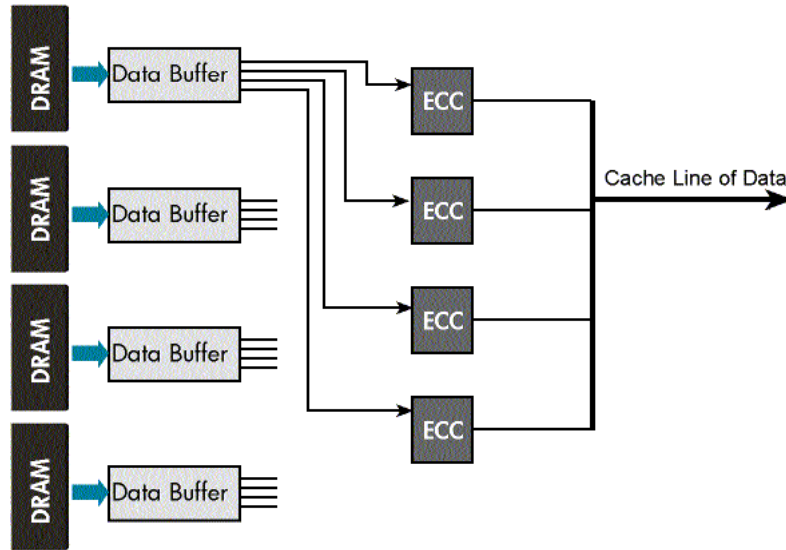
ECC technology has provided adequate protection for many applications. However, the effectiveness of ECC protection decreases as memory capacity rises. This fact is significant because of the following factors driving industry-standard servers to support more memory capacity:

- operating systems now support greater amounts of memory;
- low-cost, high-capacity memory modules are more available;
- server virtualization.

Advanced ECC technology

To improve memory protection beyond standard ECC, HP introduced Advanced ECC technology in 1996. HP and most other server manufacturers continue to use this solution in industry-standard products. Advanced ECC can correct a multi-bit error that occurs within one DRAM chip; thus, it can correct a complete DRAM chip failure. In Advanced ECC with 4-bit (x4) memory devices, each chip contributes four bits of data to the data word. The four bits from each chip are distributed across four ECC devices (one bit per ECC device), so that an error in one chip could produce up to four separate single-bit errors. Figure 4 shows how one ECC device receives four data bits from four DRAM chips.

Figure 3. In Advanced ECC, each DRAM chip sends four data bits, which are distributed across four ECC devices.



Since each ECC device can correct single-bit errors, Advanced ECC can actually correct a multi-bit error that occurs within one DRAM chip. As a result, Advanced ECC provides device failure protection (Table 1).

Table 1. Comparison of error protection with ECC and Advanced ECC

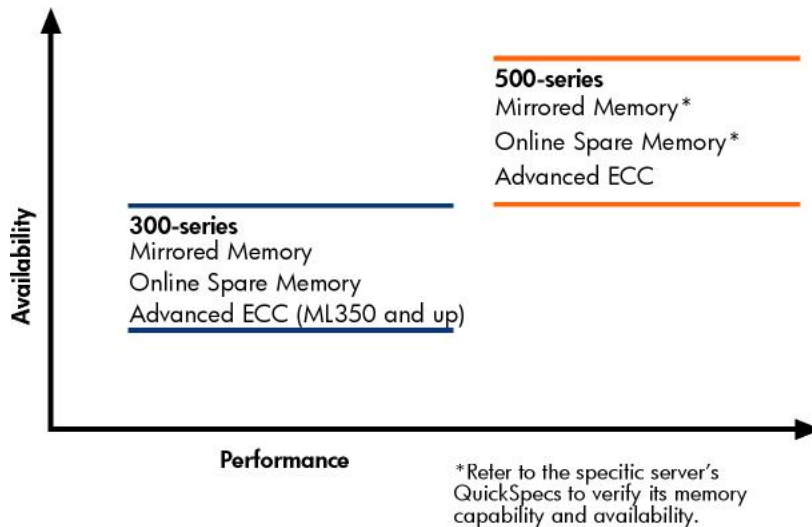
Error Condition	ECC Outcome	Advanced ECC Outcome
Single-bit	Correct	Correct
Double-bit	Detect	Correct or detect
DRAM failure	Detect	Correct
ECC detection fault	—	—

Although Advanced ECC provides failure protection, it can reliably correct multi-bit errors only when they occur within a single DRAM chip. Advanced ECC does not provide failover capability. As a result, if there is a memory failure, the system must be shut down before the memory can be replaced. The latest generation of HP ProLiant servers offers two levels of Advanced Memory Protection that provide increased fault tolerance for applications requiring higher levels of availability.

HP Advanced Memory Protection technologies

Most HP ProLiant 300- and 500-series servers feature one or more Advanced Memory Protection technologies that deliver increased fault tolerance for applications requiring higher levels of availability. These Advanced Memory Protection technologies—Online Spare Memory and Mirrored Memory—are optimized for the features and applications of each server series (see Figure 4).

Figure 4. Advanced ECC and HP Advanced Memory Protection technologies in the latest generation of HP ProLiant servers



Online Spare memory

Online Spare memory mode is a higher level of memory protection that complements Standard Memory mode with Advanced ECC. With Online Spare mode, a DIMM with a rank of memory at least as large as the other ranks in the system, or memory board, is designated as the Online Spare rank.² If one of the other DIMMs exceeds a threshold rate of correctable memory errors, the affected rank of memory within that DIMM is taken offline and the data is copied to the Online Spare rank. This capability maintains server availability and memory reliability without service intervention or server interruption. The DIMM that exceeded the error threshold can be replaced at the customer's convenience during a scheduled shutdown. Online Spare reduces the chance of an uncorrectable error bringing down the system; however, it does not fully protect the system against uncorrectable memory errors.

Online Spare mode is beneficial to businesses with sites that do not have IT staff available to service a failure, do not always have replacement memory readily available, or cannot bring down the server until a scheduled shutdown. The cost of implementation for Online Spare over Advanced ECC is the hardware cost of the extra DIMMs for the spare memory bank.

The user configures the system for Online Spare mode through the RBSU³. Online Spare configuration requirements vary for each server series, but it does not require operating system support or special software beyond the System BIOS. However, if messaging and logging are desired at the console

² For more information about memory ranks, refer to the technology brief "Memory technology evolution: an overview of system memory technologies" edition at <http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00256987/c00256987.pdf>.

³ Please read the user guide for each server for instructions to run RBSU.

along with messages in HP Systems Insight Manager, an operating system must be used that has system management and agent support for Advanced Memory Protection.

For information about whether specific ProLiant server support for Online Spare memory, refer to the QuickSpecs for the server.

Mirrored Memory

Mirrored Memory mode is a fault-tolerant memory option that provides a higher level of availability than Online Spare mode. While Online Spare mode protects against single-bit errors and entire DRAM failure, Mirrored Memory mode provides full protection against single-bit and multi-bit errors.

To enable Mirrored Memory mode, customers designate half of the memory banks as system memory and the remaining banks as mirrored memory. All banks must be configured identically.

In Mirrored Memory mode, the same data is written to both the system memory and mirrored memory banks, but data is read only from the system memory banks. If a DIMM in the system memory banks experiences a multi-bit error or reaches the pre-defined error threshold for single-bit errors, the system will still write data to both the system and mirrored memory banks. However, the system will only read data from the mirrored memory banks. This allows continuous operation and maintains the level of server availability except in the highly unlikely case of a simultaneous error in exactly the same location on a DIMM and its mirrored DIMM.

Interline comparison

Table 2 provides an interline comparison and competitive advantage of HP Advanced Memory Protection technologies to Advanced ECC. All technologies shown provide device failure protection.

Table 2. Advanced Memory Protection interline comparison and competitive advantage

	HP Advanced ECC Technology	HP Online Spare Memory	HP Mirrored Memory
Device failure protection	Yes	Yes	Yes
Industry-standard DIMMs	Yes	Yes	Yes
Failed DIMM replacement	Offline	Offline	Offline
Additional memory expense	0%	10% – 50%	100%

Conclusion

The demand for servers with more memory capacity is unrelenting—it is driven by increasingly complex and memory-intensive applications and more powerful processors. While meeting the demand for more system memory, 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.

HP is meeting the challenge with fault-tolerant memory protection technologies: Online Spare Memory and Mirrored Memory. Online Spare Memory is beneficial to customers with sites that cannot afford downtime from memory errors, yet can wait until a scheduled downtime to replace failed memory modules. Mirrored Memory provides a higher level of availability with a more fault-tolerant option providing full protection against single-bit, and multi-bit errors.

These HP Advanced Memory Protection technologies enable customers to choose a system with the level of memory availability they prefer to enhance the robustness of their final solution.

For more information

For additional information, refer to the resources detailed below.

Resource description	Web address
“Memory technology evolution: an overview of system memory technologies” technology brief	http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00256987/c00256987.pdf
Implementation of key technologies in ProLiant servers	http://h18004.www1.hp.com/products/servers/technology/whitepapers/proliant-servers.html
Industry Standard Server Technology Papers	www.hp.com/servers/technology/
HP ProLiant DL380 G5 QuickSpecs (North America)	http://h18004.www1.hp.com/products/quickspecs/12477_na/12477_na.html
HP ProLiant DL360 G5 QuickSpecs (North America)	http://h18004.www1.hp.com/products/quickspecs/12476_na/12476_na.html
HP ProLiant ML370 G5 QuickSpecs (North America)	http://h18004.www1.hp.com/products/quickspecs/12478_na/12478_na.html
HP ProLiant QuickSpecs (Worldwide)	http://h18000.www1.hp.com/products/quickspecs/ProductBulletin.html#intro

Call to action

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TC080405TB, April, 2008

