Dell™

Reliable MemoryTechnology PRO

Detecting and isolating memory errors
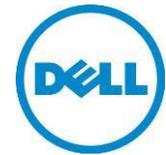
Overview

Regardless of make, manufacturer or type, almost all computer-based memory has some type of inherent infinitesimal error or defect. A memory manufacturing vendor may spend between 10-15% of the cost of a dual in-line memory module (DIMM) running extensive testing for errors, and still memory can be prone to failure at some point in its life. Any number of variables can cause memory errors — from heat to age to tiny defects.

In fact, dynamic random-access memory (DRAM) error rates are orders of magnitude higher than had been previously reported. In a recent large-scale study of DRAM memory errors in the field based on data collected over a period of more than two years, about a third of all machines and over 8% of DIMMs saw at least one correctable error per year[1]. With some platforms seeing nearly 50% of their machines affected by correctable errors[2], only about 1.3% of systems were affected by uncorrectable errors per year, with some platforms seeing as many as 2-4% affected.[3]

For a standard office personal computer system, memory errors rarely adversely affect the outcome of standard business-class application software.

However, in the high-end, computation-intensive world of finance, oil and gas research, medical imaging, media production (rendering and editing), among others, data integrity is a crucial component of the overall system architecture. In such high-performance systems, memory replacement ranks near the top of component replacements, with memory errors showing up as one of the most common hardware issues that can lead to system crashes. [4]

Therefore, the ability to detect, report and prevent DIMM errors becomes a necessity in high-performance workstations.

Understanding the critical demand for extreme memory performance, Dell patented an innovative, exclusive technology applicable to Dell Precision™ workstation systems that helps to mark and map out unusable memory. This unique Dell feature helps reduce system downtime, free up IT support time, and drive down overall maintenance costs while increasing memory longevity and user productivity.

This paper introduces the basic concepts of Dell Reliable Memory Technology PRO (RMT PRO) and looks at some of the root causes of memory errors and how RMT PRO helps to remediate and obviate memory errors.

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[1] "DRAM errors in the wild: a large-scale field study", p. 194, Bianca Schroeder, University of Toronto, Toronto, ON, Canada; Eduardo Pinheiro and Wolf-Dietrich Weber, Google Inc., Mountain View, CA, USA; SIGMETRICS '09 Proceedings of the eleventh international joint conference on Measurement and modeling of computer systems, ACM New York, NY, USA ©2009 ISBN: 978-1-60558-511-6
[2] IBID, p.195
[3] IBID, p.196
[4] IBID, p.193
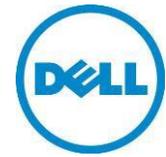
Memory Primer 101

As computer systems have become more sophisticated with evolutionary advancements in processors, bus speeds, and overall architecture, memory likewise has needed to keep pace with these enhancements.

> NOTE: For this discussion of memory, or random access memory (RAM), we reference the memory modules outside of the processor core (known as CPU cache memory, or L1/L2 — which is beyond the scope of this discussion.

Essentially (and *very* simplistically), DRAM chips are an array of on/off switches that store a state (1 or 0) as long as they have a flow of current (i.e., when the power is off, they reset to a null state). Multiple chips are assembled together to build a memory subsystem and organized onto a circuit board known today as the ubiquitous DIMM (dual in-line memory module).

Most workstations, such as Dell Precision Workstations, use the most advanced type of DIMM known as DDR4 SDRAM (double-data-rate-three synchronous dynamic random access memories). Essentially, compared to earlier versions of memory types (e.g. DDR3), DDR4 is faster, has greater through-put, requires less voltage, and can accommodate more memory density.
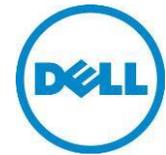
Memory Errors

Memory errors can be caused by any number of factors, resulting in a single bit of DRAM to spontaneously flip to the opposite state (i.e., it flips from 1 to 0 when it should have remained a 1 during that memory cycle). Factors such as heat, age, defects, etc., can contribute to these errors. In fact, studies have shown that beyond the first 10 months of a DIMMs life the rate of errors increases dramatically[5].

These types of errors are known as 'soft errors', or correctable errors, which randomly corrupt bits but do not leave physical damage and can be corrected via a memory refresh.

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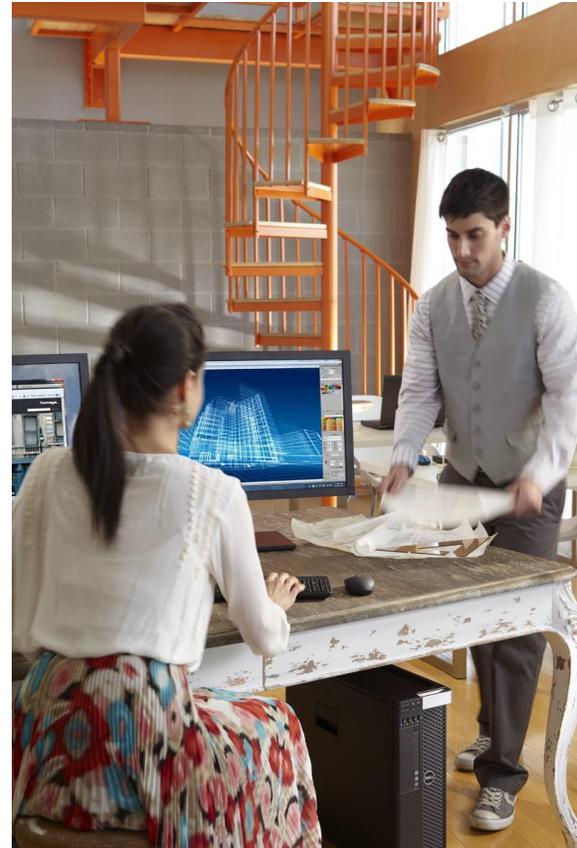
[5] IBID, p.202

In many cases, memory errors are dominated by 'hard errors', or uncorrectable errors – errors which corrupt bits in a repeatable manner because of a physical defect or other anomaly within the DIMM itself – or when two soft errors occur within the same block of memory. A hard memory error can cause a machine "crash" (reboot required) or applications to fail (generating a system-level Stop Error code such as a kernel panic or the blue screen of death, BSoD). Often soft errors are warning signs of impending hard errors. In field-based research, about 65-80% of uncorrectable errors were preceded by a correctable error in the same month[6]

Error Handling

Many workstation class PCs today incorporate memory parity checking algorithms, which to put it simply, ensures that the data sent is the same as the data received every time a byte of data is read.

More sophisticated systems use other types of error correction and detection methods. The most common, error-correcting code (ECC) memory is used in servers and workstations, such as Dell Precision Workstations. Essentially, ECC memory includes extra memory bits and an on-board memory controller that checks for memory parity and 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. Bottom line: ECC is great at correcting isolated soft memory errors and provides a solid foundation for memory and system stability. However, ECC memory provides no solution for multiple hard errors or soft errors within the same block of memory. In these instances data corruption will occur. This is where Dell Reliable Memory Technology PRO can help.

The Benefits of RMT PRO

When a hard disk drive has physical damage to the platter, that sector is reported, mapped and marked as unusable by the PC system. However, in most PCs today, even workstations running ECC memory, a hard error or multiple soft errors in the same memory block on a DIMM is simply noted, which could cause a system crash. The user must normally report the error to their IT help desk, which in turn must run some diagnostic to detect the error. Most often, a single bit failure may precipitate the replacement of the entire DIMM.

The result: Increased cost in the form of downtime, lost user productivity, IT personnel time, DIMM replacement and possible corruption of key application files.

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[6] IBID, p. 196
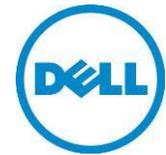
Enter Dell Reliable Memory Technology PRO (RMT PRO). Similar in concept to hard drive error- mapping technology, RMT PRO detects hard errors and multi-bit soft errors in a DIMM, and obviates and remediates the problem. Instead of having to incur costly downtime and IT services such as calling IT, running diagnostics, opening the system, and replacing the faulty DIMM, upon reboot RMT PRO:

- Maps the defective portion of the individual DIMM
- Reports the defect and DIMM location in the BIOS as bad
- Removes these bad cells and a small amount of nearby cells from system memory usage

With a simple system reboot, RMT PRO removes the defective area from visibility to the operating system. Applications and critical systems functions will now by-pass any marked area and continue working without having to replace hardware. It's as if the bad memory never existed, ensuring smooth, error free operation, helping to reduce system crashes and application errors.

In fact, RMT PRO can help reduce memory hardware costs over time. As memory may deteriorate with increased usage or excessive heat (normally due to extreme usage), physical errors may increase. The "bad memory"

information stays with the DIMM, even if it is moved internally within the system. In addition, if DIMM replacement is needed, RMT PRO will display in the BIOS which DIMM(s) are causing errors, making trouble shooting and DIMM replacement faster and easier helping to reduce downtime and overall cost.

RMT PRO extends the lifecycle of existing memory and helps contribute to cost savings over time.

Conclusion

Although some error detection schemes can catch memory errors, such as ECC memory, many of these algorithms can only handle soft errors. When physical defects or hard errors within a DIMM occur, Dell RMT PRO provides an extra layer of bad memory detection and correction.

By mapping and removing the bad sectors, RMT PRO helps ensure that compute-intensive applications are accessing good and usable memory. This can result in significant savings in both time and money due to a reduction in replacement DIMM hardware and IT personnel and end user downtime.

When data integrity is crucial, RMT PRO provides a much needed layer of assurance, delivering useable memory to maximize workstation processing capacity and reliability.