The Importance of ECC Memory in Your Substation Computer

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Introduction

Utility substations are environments that require highly reliable computing systems. Failures are costly and can cause service disruptions to customers across wide geographical areas. Substation computing systems are being installed at a faster pace than ever before and used for a diverse set of applications. These applications include: protocol converters, data concentrators, supervisory control and data acquisition (SCADA), local human-machine interface (HMI), remedial action schemes, distribution automation, cybersecurity, historians, and wide-area measurement and control.

There are many ways to make substation computers reliable, including hardening the computer to meet protective relay specifications (with wide temperature ranges, vibration tolerance, and electrostatic shock resistance) and designing the computer with no moving parts.

This white paper addresses another method of increasing the reliability of substation computers—designing them to use error-correcting code (ECC) memory. The use of ECC memory minimizes the specific memory error class of single bit flips. Almost all server-class computers use ECC memory, but very few substation computers use ECC memory.

Error Rates and Their Effects on System Reliability

Substation computers with 2 GB RAM (random-access memory) can expect to experience one bit flip every other week because of cosmic ray influence on the RAM. These bit flips can cause the computer to crash. SEL uses ECC memory in its substation computers to detect and correct these bit flips before they can cause problems.

According to an Advanced Micro Devices, Inc. (AMD) study on soft error rates (SER), "a typical SER might be one bitflip per 2-4 weeks per gigabyte of DRAM. To put this another way, a 4GB system can expect to encounter roughly one error each week" [1]. The first large-scale study in the field, which used a fleet of server computers owned by Google™, was released in 2009. Over a period of two-and-a-half years, using data from thousands of machines in the field, the study found that dynamic random-access memory (DRAM) "mean correctable error rates were 2000-6000 per GB per year" [2].

Memory errors are the leading cause of system crashes [3]. "To handle an ECC-error interrupt current operating systems, including both Linux and Microsoft Windows, simply go to the panic mode or the blue screen … The user has to reboot the machine to solve the problem" [4]. The study by Google states, "a memory error can lead to a machine crash or applications using corrupted data" [2]. According to Hewlett-Packard Company (HP), "perhaps 2% to 15% of soft errors will affect the result of a customer calculation significantly – resulting in incorrect answers, system crashes, or unpredictable behavior" [5].

Memory errors have also been shown to cause security vulnerabilities [6] [7]. "According to the US-CERT Vulnerability Notes Database, 39% of all reported vulnerabilities since 1991 were caused by memory leaks or memory corruption, and 55% of the most severe vulnerabilities are related to them. In the year of 2003, these two types of bugs contributed to 68% of the CERT/CC advisories" [4].

ECC Memory Significantly Reduces Error Rates

ECC memory with single error correction (SEC) algorithms can reduce soft and hard memory errors [8]. This error class is where a single bit in memory can accidentally flip—becoming a zero when it should be a one or a one when it should be a zero. "ECC protection provides a significant reduction in failure rates (typically, more than a 10,000 [times] reduction in effective error rates)" [9].

Experimental studies show reliability for non-ECC memory of size 32Kx64 to be 344 hours versus reliability for SEC ECC memory of the same size to be 28,010 hours [8].

The Google study shows that 32.2% of all machines in the fleet experienced an average of 277 errors per year that were correctable with ECC memory and 1.3% of machines encountered memory errors that were not correctable with ECC memory [2]. While not specifically stated in the study, it would be safe to say that if ECC memory had not been used with the 32.2% of machines that encountered correctable memory errors, they would have been left uncorrected, which usually results in a machine shutdown.

An International Business Machines Corporation (IBM®) study effectively showed a comparison of nine outages with ECC memory compared to 224 outages with non-ECC memory. Specifically, the study says, "the 1GB ECC memory-equipped server received 9 outages per 100 servers over 3 years" and "the 32 MB parity memory-equipped (non-ECC) server received over 7 outages per 100 servers over 3 years" [10]. Extrapolating the 32 MB results to a 1 GB non-ECC system results in 224 outages for non-ECC memory.

The Google and IBM real-world studies show a very clear consistency of non-ECC memory systems having 25 times more outages compared to systems with ECC memory. HP released a study in a real-world environment that showed that 28 systems out of 100 with 1 GB of memory will experience memory errors. These would all be correctable with ECC memory [5].

ECC Memory Performance and Cost Differences

As you might expect, to get these benefits, the use of ECC memory may result in slight performance degradation, depending on the application. In addition, ECC memory will also cost slightly more than conventional memory, because both the memory chips and the motherboard to support them are more expensive. Estimates show ECC memory can be 2 to 3% slower, which becomes negligible in overall computing system performance, when compared to processor operating speeds, disk reads and writes, and input and output (I/O) throughput. The extra cost of ECC memory in current prices for 1 GB varies between $0 and $15, depending on performance and manufacturer.

Power system applications tend to be mission-critical; thus, SEL customers are more than willing to accept negligible performance effect and slightly higher cost by using ECC memory in their substation computers to ensure much greater reliability.

SEL COMPUTER SYSTEMS USE ECC MEMORY

SEL designs and manufactures products for utility substation environments and recognizes the importance of the reliability of these products, including substation computing products. To achieve the highest reliability, SEL designs, manufactures, and tests computers to the utility industry protective relay standards, such as ANSI/IEEE 1613, ANSI/IEEE C37.90, IEC 60255, and IEC 61850-3. The computer hardware has no moving parts or fans. With an on-board power supply, unique thermal design, ECC memory, solid-state storage, and an integrated watchdog controller and system monitoring software, SEL tough industrial computers achieve the best in reliability. SEL tough industrial computers have a field-proven mean time between failures (MTBF) of over 70 years and come with a worldwide, ten-year product warranty.

SEL substation computers are designed with ECC memory to detect and correct frequent bit flips in RAM that can cause the substation computer to crash. With the critical use of substation computers and safety on the line, SEL customers are willing to accept a negligible performance effect and slightly higher cost by using ECC memory.

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BIOGRAPHY

John Harrell received his M.S. in Computer Engineering at Santa Clara University in 1991 and his B.S. in Mathematics at California Polytechnic State University in 1984. He has worked in a variety of engineering and marketing management and executive positions for companies including IBM, Sun Microsystems, and Sybase. His engineering work includes DSP firmware development and distributed control systems. John started working at Schweitzer Engineering Laboratories, Inc. in 2007 as product manager for computing systems.

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