# ECC vs. Non-ECC MEMORY

## Whitepaper

Document #AN0031 – ECC vs. Non-ECC Memory Whitepaper | Rev A

### Purpose of this Document

This application note was prepared to help OEM system designers evaluate the performance of Viking solid state drive solutions by using the same benchmarking methodology that Viking performs in it's SSD test facility. The SSD performance stated in the Viking SSD datasheets can be achieved by following the same Viking approach to SSD benchmarking which has been outlined in this document

viking TECHNOLOGY | A RF, Optical, Microelectronics and Memory Company

**Abstract**

Viking Technology manufactures DRAM modules for OEMs in Enterprise, Telecommunications and Industrial markets. It offers Full DRAM technology portfolio from DDR4 to Legacy DDR1. Viking's modules follow JEDEC standard and range from Standard Form Factors to the most comprehensive small form-factor and Specialty custom modules. Each memory module comes with either ECC or non-ECC. ECC (error correction code) memory is memory that is able to detect and correct some SDRAM errors without user intervention. Most non-ECC memory cannot detect errors

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## 1 What is ECC memory?

ECC memory (Error-correcting code memory) [Figure-1] is a type of computer data storage (memory) that can detect and correct the most common kinds of internal data corruption (errors) without user intervention. ECC memory is used in most computers where data corruption cannot be tolerated under any circumstances, such as for scientific or financial computing. ECC memory replaced parity memory which could only detect, but not correct memory errors.

Typically, ECC memory is very popular in servers or other systems with high-value data as it maintains a memory system immune to single-bit errors: the data that is read from each word is always the same as the data that had been written to it, even if one or more bits actually stored have been flipped to the wrong state. Most non-ECC memory [Figure-2] cannot detect errors although some non-ECC memory with parity support allows detection but not correction.

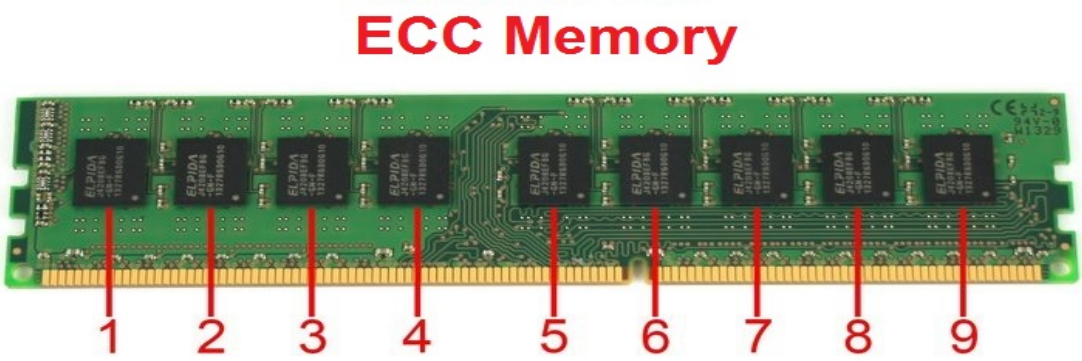


Figure-1: Example of ECC Memory

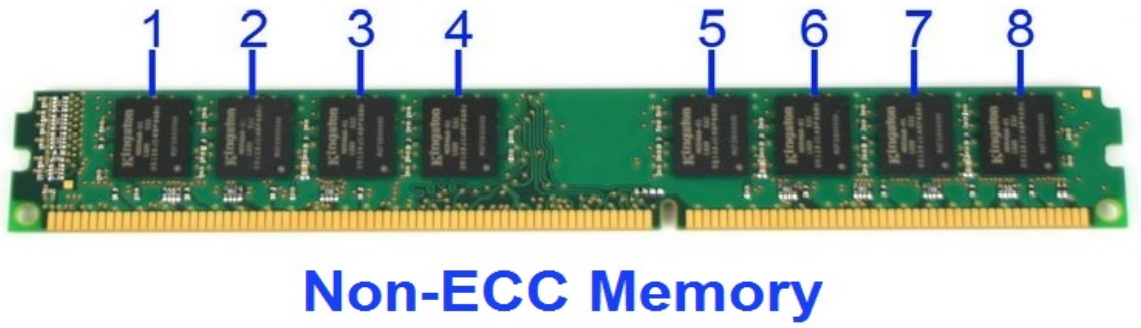


Figure-2: Example of Non-ECC Memory

Standard RAM uses banks of eight memory chips in which data is stored and provided to the CPU on demand. ECC memory or ECC RAM is different as it has an additional memory chip which acts as both error detection and correction for the other eight RAM chips. While marginally more expensive than non-ECC RAM, the added protection it provides is critical as applications become more dependent on large amounts of data.

## 2 What is ECC (Error Checking and Correction)?

Early on, RAM was not as stable a solution as it is today. Irregularities could cause the data in memory to corrupt or alter in ways that often led to a system crash or hard disk data damage. This problem was first solved via even or odd parity bits. In a computer, data is most commonly stored in 8-bit chunks. When parity is being used, an additional ninth bit - or parity bit - is written which allows the system to detect when there is an error. If the system uses even parity, then the 1's and 0's (including the additional parity bit) should add up to an even number. In an example of even parity [Table-1], the second one fails because one bit was read incorrectly. Parity is usable in small runs of data as a safeguard, but as the blocks of information get larger, the process becomes slower. Parity also cannot automatically correct the error, except by reloading the data.

| Byte | Addition(+) | Parity Bit | Final Outcome |
|---|---|---|---|
| 00000000 | + | 0 | 0 |
| 10000001 | + | 1 | 3 (Fail) |
| 11100000 | + | 1 | 4 |
| 10000000 | + | 1 | 2 |

Table-1: Example of Even Parity

ECC is an extension to parity as it uses multiple parity bits assigned to larger chunks of data to not only detect single bit errors, but correct them automatically as well. Instead of a single parity bit for every 8 bits of data, ECC uses a 7 bit code that is automatically generated for every 64 bits of data that is stored in the RAM. When the 64 bits of data is read by the system, a second 7 bit code is generated, and then compared to the original 7 bit code. If the codes match, then the data is free of errors. If the codes do not match, the system can determine where the error is and fix it by comparing the two 7 bit codes. The method of comparing the two codes is most commonly done by what is called the Reed-Solomon code.

Due to this check process, ECC RAM is slightly slower. Depending on the brand and model, this drop in speed averages between 1% and 2%. A 2% reduction of speed is unlikely to be noticeable to a human user for most standard applications. SQL databases may slow down by a minimal amount as their memory usage peaks, however this reduction of speed is acceptable to prevent a loss of critical data.

If the data did not check out properly, your computer would typically halt to avoid further problems. ECC added a further process to the cycle. Instead of merely checking the bytes, it can correct most errors with an extra bit. It is fairly popular with the CAD crowd, as it helps maintains strict accuracy. For most consumers, however, it is not necessary due to the low rate of errors in today's memory, and actually involves a slight performance hit.

## 3 Likelihood of a memory error

On any server with critical data such as financial information or critical personal information, especially medical, any data loss or transcription error is unacceptable. Memory errors can cause security vulnerabilities, crashes, transcription errors, lost transactions, and corrupted or lost data.

The chances of a memory error occurring are estimated by experts to occur at rates of 2000–6000 per GB per year of uninterrupted operation. While desktop computers may not have noticeable memory errors very often, systems that operate for long periods of time, like data-centric servers, are at a greater risk. The risk also increases with larger amounts of memory and the age of the system. In a sensitive, high-demand work environment, all caution must be taken to prevent any likelihood of errors.

## 4 Single-Bit Errors

A single-bit error is when one bit (a binary 1 or 0) of a byte of data (8 bits) is changed to the opposite value (1 to 0, or vice versa). It is the most likely error to corrupt data, as it is so small that the computer may not automatically recognize it as incorrect

data. Multiple bit errors (more than 1 bit being simultaneously affected), are more likely to occur, but less likely to be accepted by the computer as valid input. Multiple bit errors can be detected by single-bit ECC, but may not be corrected by it in all instances. Instead the system ignores it and reloads the data.

There are two types of single-bit memory errors: hard errors and soft errors. Physical factors, such as defects in the silicon or metallization of the memory package, voltage stress, impact shock, temperature variation, or other nominal hardware damage, cause hard errors. This could be due to a manufacturer error, mishandled hardware, or it can simply be caused by stress over time. Hard errors are usually permanent once they manifest. On the other hand, soft errors are caused by charged particles or radiation, and are transient. Soft errors are also caused by data being written or read differently than originally intended. As data is moved in and out of RAM, some corruption naturally occurs. Since bits retain their programmed value in the form of an electrical charge, there are many potential causes of these errors. Theories of why this occurs range from naturally occurring isotopes emitting Alpha particles, cosmic rays, magnetic variances, fluctuations in electricity flow, and even electromagnetic interference (EMI) from the computer itself.

Most ECC SDRAM can correct single bit errors, and detect, but not correct larger errors. Thus, errors greater in size than 1 bit will still crash the computer. So, large server manufacturers have implemented additional error correcting hardware capabilities with a technology known as Chipkill. Chipkill correct is the ability of the memory system to withstand a multibit failure within a SDRAM device, including a failure that causes incorrect data on all data bits of the device. These methods rely on the chip set and hardware architecture of the system and cannot be achieved through software upgrades.

## 5 Registered Memory

Registered (often referred to as "buffered") memory uses a technology that is often paired with, but not directly related to, ECC RAM. Registered memory has a "register" that resides between the RAM and the system's memory controller which lessens the load that is placed on the memory controller itself. This allows for more memory modules to be used at one time than would otherwise be possible.

While ECC RAM is not always registered (since you may need the error correction of ECC without the large quantities made possible by registered memory), almost all registered memory will be ECC. This is simply due to the fact that systems that use large amounts of memory are almost always going to prioritize stability as well.

## 6 Advantages and disadvantages of ECC RAM

ECC protects against undetected memory data corruption, and is used in computers where such corruption is unacceptable, for example in some scientific and financial computing applications, or in file servers. ECC also reduces the number of crashes, particularly unacceptable in multi-user server applications and maximum-availability systems. Most motherboards and processors for less critical application are not designed to support ECC so their prices can be kept lower. Some ECC-enabled boards and processors are able to support unbuffered (unregistered) ECC, but will also work with non-ECC memory; system firmware enables ECC functionality if ECC RAM is installed.

ECC is designed to be more stable than traditional RAM. However, there are a few downsides to using ECC RAM. The first, and most obvious, is that not every computer can use ECC memory. Most server and workstation motherboards require ECC RAM, but the majority of desktop systems either won't work at all with ECC RAM or the ECC functionality will be disabled.

Second, due to the additional memory chip and the inherently more complex nature of ECC RAM, it costs more than non-ECC RAM. The amount varies, but you should expect to pay roughly 10-20% more depending on the size of the memory stick. The larger the stick, the higher the price premium.

ECC RAM is slightly slower than non-ECC RAM. Many memory manufacturers say that ECC RAM will be roughly 2% slower than standard RAM due to the additional time it takes for the system to check for any memory errors.

## 7 Conclusion

If your business specializes in finance, military application, automotives, healthcare or datacenters and the server crashes while processing a transaction due to a memory error, the transaction would be lost. Memory errors could also lead to data transcription errors, where a number is changed or a decimal is misplaced. In this scenario, you may not even know the error has occurred. It could be days or weeks before that transaction is next reviewed. Even then it may still not get caught by whoever is reviewing it.

Without the added layer of error checking that ECC provides, your important data may be saved as a different code or may simply be corrupted, making it that much more difficult to categorize and track the patient properly. This could cause serious ramifications when reviewed by another specialist or the insurance company. Arguably, this could be corrected by reading the notes on the file, but it could cause a delay in response to a critical patient. Medical information is sensitive to both time and accuracy.

Security vulnerabilities, transcription errors, corrupted information, lost data, and downtime caused by system crashes all are technological complications that may be minimized or even eliminated by ECC memory. With critical information in the balance, ECC is advisable to prioritize data accuracy and system stability.

If you have a server or system with high-value data where system stability is of upmost importance, these few drawbacks are very likely not even close to being an issue. The cost of RAM has come down so much recently that even a 20% increase in price only equates to about $10 per stick, which in a server environment is a very worthwhile investment. As for the performance decrease, 2% is such a small amount that it is likely never going to be perceptible outside of performance benchmarks.

At the cost of a little money and performance, ECC RAM is many times more reliable than non-ECC RAM. And when high-value data is involved, that increase in reliability is almost always going to be worth the small monetary and performance costs. In fact, anytime it is possible to do so, we would recommend using ECC RAM.