# Superior EEPROM Endurance Using Adesto CBRAM® Products

## Introduction

Adesto CBRAM EEPROM products do not derate endurance below the datasheet specification at higher operating temperatures, voltages or when using byte write mode. Because data is stored by "conducting bridges", transistor characteristics are not degraded by damage or trapping with program/erase at high temperature or voltage. In contrast, EEPROMs which store memory states in a floating gate (FG) or charge traps (CT) only attain the specified endurance under a limited range of the specified operating conditions. Data stored in CBRAM is not erased by exposure to UV light (for example during Chip Scale Packaging) as occurs for floating gate memories. This note compares the endurance of Adesto CBRAM EEPROM devices to competitive FG products.

## Discussion

Adesto EEPROMs have true direct write operation as defined by JESD22-A117 (1) and "allow data to be written directly over old". Adesto EEPROM products compare the data to be written with the logical state of the addressed byte. Only bits which need altered are changed which leads to a doubling of the endurance definition (only a program or erase instead of both a program and erase operation for FG memory). In addition, for truly random data, statistically half of the bits to be written will need neither program nor erase as these bits are already in the desired logical state. Because this operation is so efficient, Adesto EEPROMs are true "byte write" so the rest of a page remains untouched when a single byte is written.

Both "program" and "erase" are fast, low energy operations for Adesto CBRAM EEPROMs, compared to floating gate ("FG") memories where one operation (typically "erase") is slow and requires high energy. To hide this, FG memories must perform the erase operation on many bits at once to meet the page time specification, typically erasing and rewriting an entire page plus its associated ECC code even when only a single bit has been altered. This causes an early degradation of the endurance specification when byte level data is stored and forces the user to write the entire page when only a single bit is changed.

Adesto defines endurance as the minimum number of data write cycles over which the EEPROM will store the correct data across the entire specified range of temperatures, voltages, etc. with less than the specified failure rate. Adesto customers are not constrained to a particular "usage model" of bytes per page written, temperature and supply voltage to realize the specified endurance. In addition, during qualification of Adesto CBRAM products, every bit is read and verified by comparing to the target data for every cycle instead of the common practice of only pausing endurance cycling a few times during the qualification to verify data. This ensures every bit at every cycle is in the correct logical state, which is a best practice according to JESD 22-A117. (2)

1.JESD22-A11: EEPROM device specifications often require an erase step before reprogramming data; in this case a data rewrite includes both erase and programming steps, which together are called a program/erase cycle. Direct-write memories allow data to be written directly over old, without an erase; in this case the use of the generic term 'program/erase cycle' will refer to a single rewrite with no erase.

2.JESD 22-A117: Ideal practice for endurance testing is to verify the data written after every cycle, so that transient endurance failures are detected.

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# Superior EEPROM Endurance with CBRAM®

# Application Note

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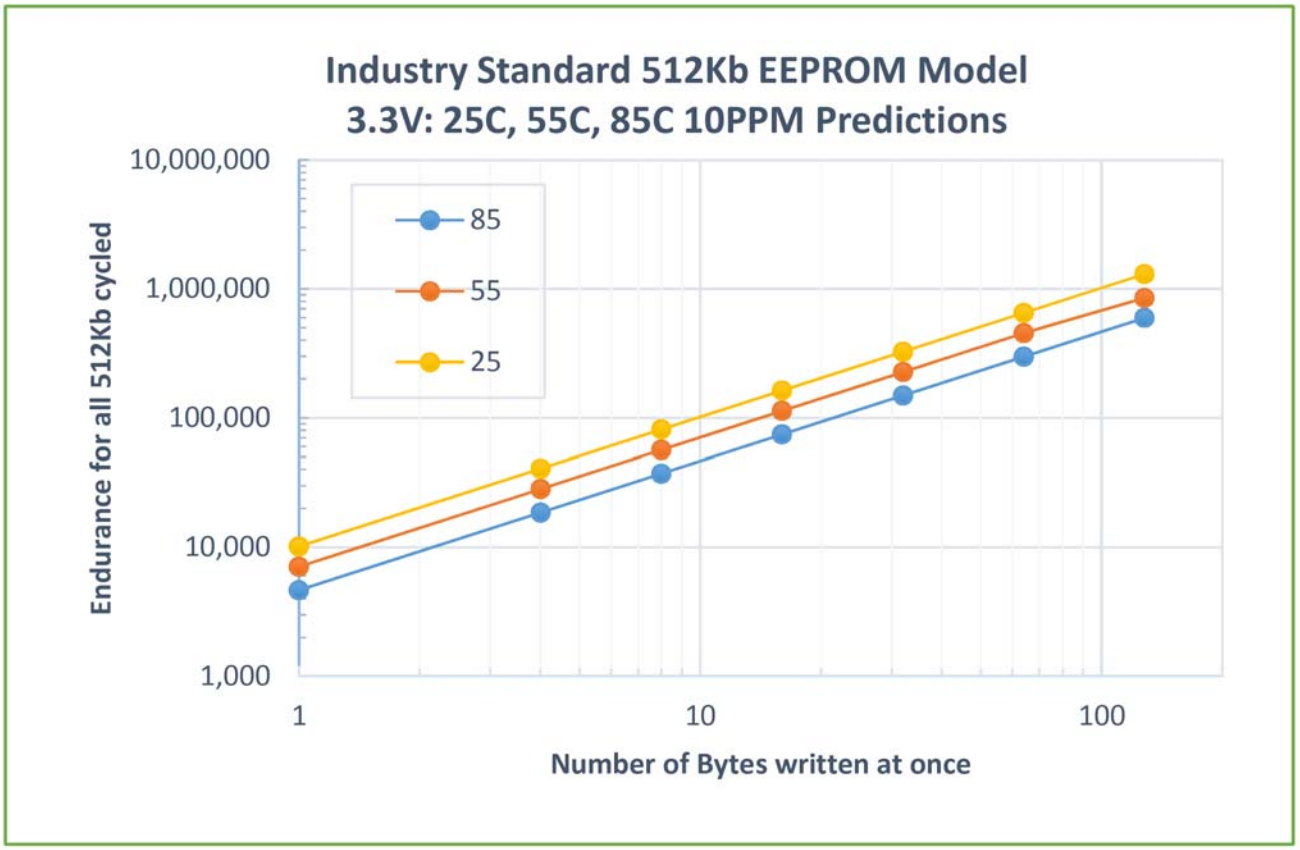
## The Effects of Using Page Write on Endurance

FG EEPROMs often require a customer to use "page mode" to achieve the desired data write times because "erase" is a slow operation best performed on many bits at once. The example below shows the effect of using page mode (in this case 128 bytes stored with every operation) on endurance. Figure 1 illustrates that to achieve the datasheet specification of one million cycles, the user must operate in page mode at 25°C, irrespective of the actual amount of data needing modification. In the case where individual bytes must be updated at higher temperature, the actual endurance can drop well below 10,000 cycles. Because Adesto EEPROMs are true byte mode devices, endurance is not degraded when using byte mode compared to page mode.

**Figure 1.** Example of FG endurance dependence on temperature and bytes changed per write.

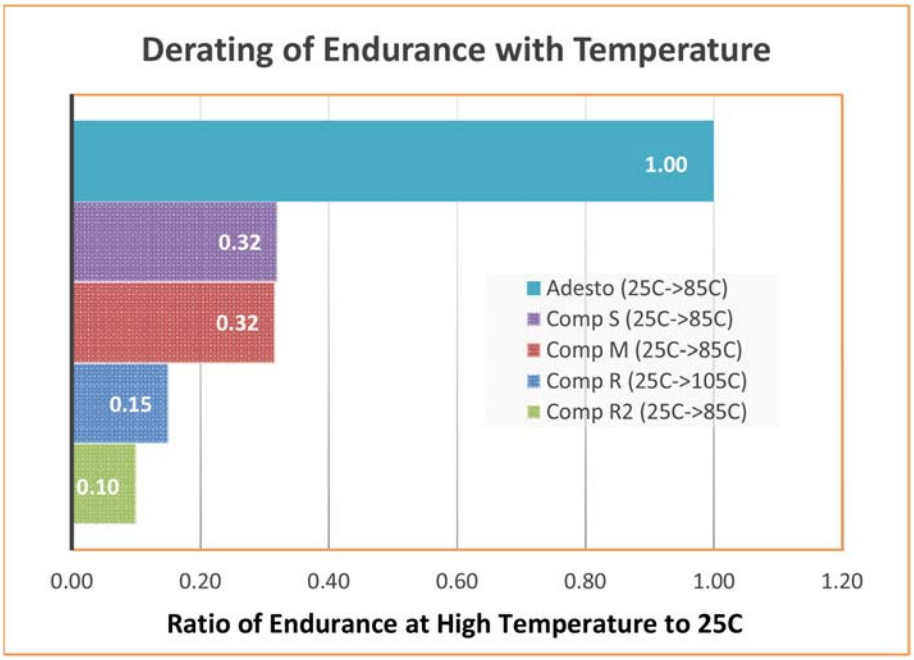



## The Effect of Temperature on Endurance

Manufacturers of FG EEPROM products often provide application notes or even calculators to enable their customers to derate the endurance specification with increasing temperature. (Typically, by 40% or more, from 25°C to 55°C.; 60% or more to 85°C - see Appendix reference links for examples). This endurance degradation of FG is particularly severe for high temperature (e.g. automotive) applications (~85% degradation).

In Figure 2, the derating of multiple industry-leading EEPROM devices is illustrated. In general, irrespective of the number of bytes written, actual endurance drops by 1/3 for most devices, while some suffer even higher derating. Adesto does not derate endurance of CBRAM EEPROMs with temperature across the data sheet range.

**Figure 2.** Temperature effect on endurance.




### Endurance Derating Example

As an example, consider a GPS log on a delivery truck that records eight bytes of random data every minute at 85°C.

Adesto EEPROMs will have the specified Data Sheet Endurance "DSE" (0 or 1 bit state change per cycle) at the highest operating temperature allowed.

| **Competitor Part De-rating:** ..... | **Resulting Endurance** |
|---|---|
| Every time a byte is changed, the whole 128 byte page is rewritten..... | DSE *8 /128 |
| Temperature is 85°C instead of 25°C on datasheet | DSE *0.32 |

Therefore, the endurance for the FG memory must be derated by a factor of ~50 (=16/0.32). If DSE for FG is one million cycles, in this application the endurance will be <= 20 thousand cycles.

## Summary

The direct write operations and “conductive bridging” technology of Adesto’s CBRAM products offer end users significant endurance benefits for applications writing bytes of data in contrast to entire pages. Higher temperatures and byte write operation on nonvolatile memories using floating gate technology result in far lower endurance than specified in the maunfacturers’ datasheets. Adesto CBRAM EEPROM products do not derate endurance below the datasheet specification at higher operating temperatures, voltages or when using byte write mode.

## Appendix

Manufacturers of floating gate EEPROMs often provide application notes or even calculators to enable their customers to derate the endurance specification with temperature.

See the links below for examples.

http://www.microchip.com/stellent/groups/SiteComm_sg/documents/Training_Tutorials/en532276.pdf
http://ww1.microchip.com/downloads/en/AppNotes/01019A.pdf
http://www.microchip.com/developmenttools/productdetails.aspx?partno= totalendurancesoftware
http://www.st.com/content/ccc/resource/technical/document/application_note/bd/19/70/43/6b/f2/4d/83/DM00158157.pdf
http://www.rohm.com/web/eu/products/-/product/BR25A512FVT-3M
https://www.renesas.com/en-us/doc/products/memory/r10ds0221ej0200_eeprom.pdf

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