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WHITE PAPER

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Data Retention Performance of 0.13-µm F-RAM Memory

Abstract

F-RAM (Ferroelectric Random Access Memory) is a nonvolatile memory that uses a ferroelectric capacitor for storing data. It offers higher write speeds over Flash/EEPROM.

This white paper provides a brief overview of data retention performance of F-RAM memory.

Introduction

This document confirms the data retention specifications of AEC-Q100 Grade 3, Grade 2, and Grade 1 (0.13 µm) F-RAM Memory Products. If operated within the product specification and with 2T2C cell structure, F-RAM has theoretically unlimited Same State (SS) data retention and limited Opposite State (OS) data retention. The prediction of OS retention time of 0.13-µm F-RAM Memory Products is based on the reliability test results after extended bakes and the activation energy (Ea) of 1.4 eV. This paper provides a method to calculate the OS data retention life time for customized temperature profiles.

F-RAM Retention Lifetime

A primary measure of reliability of F-RAM is the retention lifetime of a capacitor cell that has been previously stored in a polarization state for an extended time and then written to the opposite polarization state. This type of retention is known as Opposite State (OS) retention. The effect of imprint makes the previously stored state, or so-called Same State (SS), more stable with longer store time. Therefore, F-RAM has an unlimited SS retention life within the specified temperature range. This white paper focuses on OS retention performance. OS Retention is often specified as an amount of time at a given constant temperature. Thus the OS retention (time) specification of AEC-Q100 Grade 3, 2, and 1 F-RAM products for constant temperature profiles are given along with a cumulative scenario of multiple temperature profiles over the life of the product.

AEC-Q100 Grade 3 (Automotive-A) F-RAM OS Retention

Based on accelerated and extended stress experimental results and Ea of 1.4 eV, 10 years of OS retention at 85 ºC is guaranteed. The OS retention time at various temperatures are calculated as shown in Figure 1. The OS retention increases exponentially as temperature decreases. For example, it is 38 years at 75 ºC and >100 years at 65 ºC. Below 65 ºC, the OS retention is virtually unlimited.

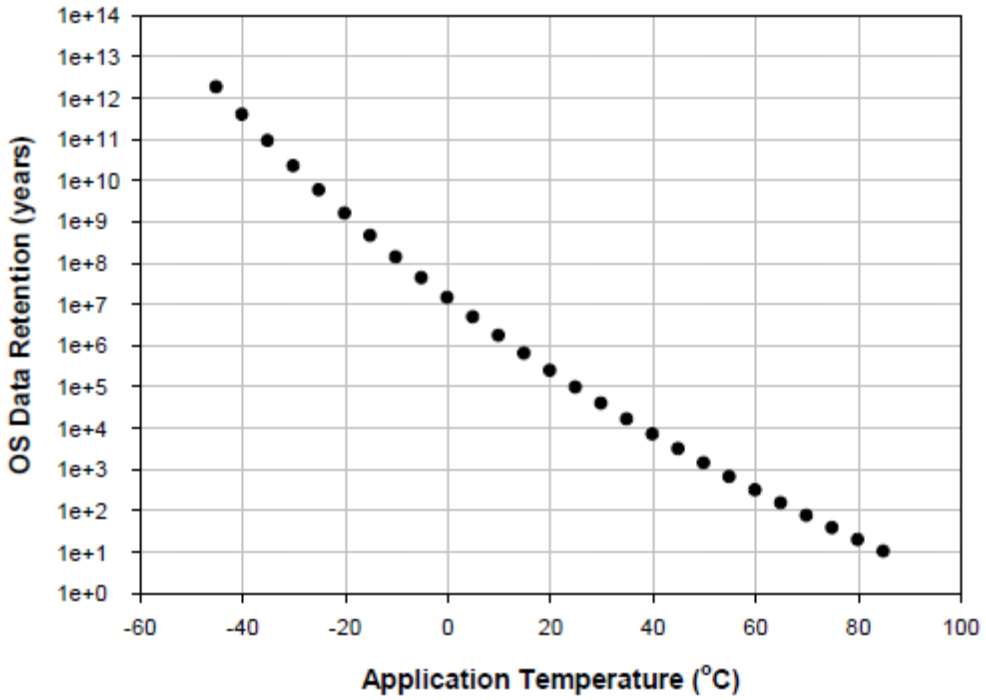

Figure 1. OS Retention Time of Automotive Grade 3 F-RAM at Various Temperatures

AEC-Q100 Grade 2 F-RAM OS Retention

Based on accelerated and extended stress experimental results and Ea of 1.4 eV, 5 years or 43.8 khours of OS retention at 105 ºC is guaranteed. The OS retention time at various temperatures are calculated as shown in Figure 2. This specification can be converted to more common temperatures. For example, it is equivalent to 43 khours at 105 ºC plus 64 years at 55 ºC. The life time prediction for specific application temperature profiles will be discussed in a later section.

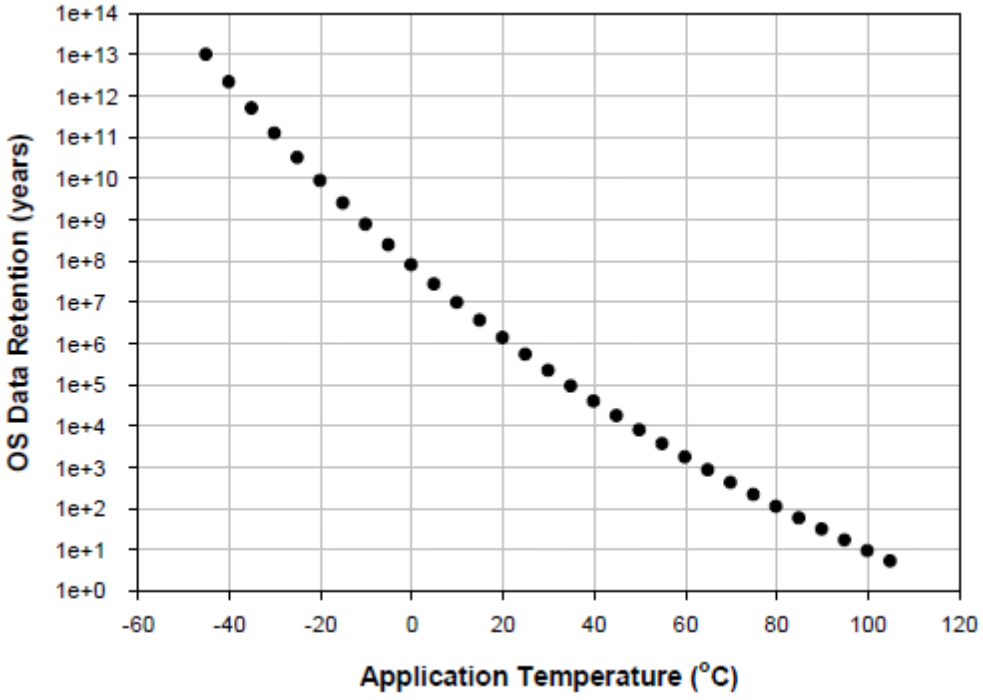

Figure 2. OS Retention Time of Automotive Grade 2 F-RAM at Various Temperatures

AEC-Q100 Grade 1 (Automotive-E) F-RAM OS Retention

The accelerated and extended stress experimental results suggest that the OS retention time of Grade 1 F-RAM products is >11,163 hours at 125 ºC. This result supports the specification of 11,000 hours at 125 ºC. The specified OS retention time at various temperatures within the specified temperature range (-40 ºC to 125 ºC) are calculated as shown in Figure 3. The specification can be converted to other temperature profiles. The life time predication of specific application temperature profiles is illustrated in the next section.

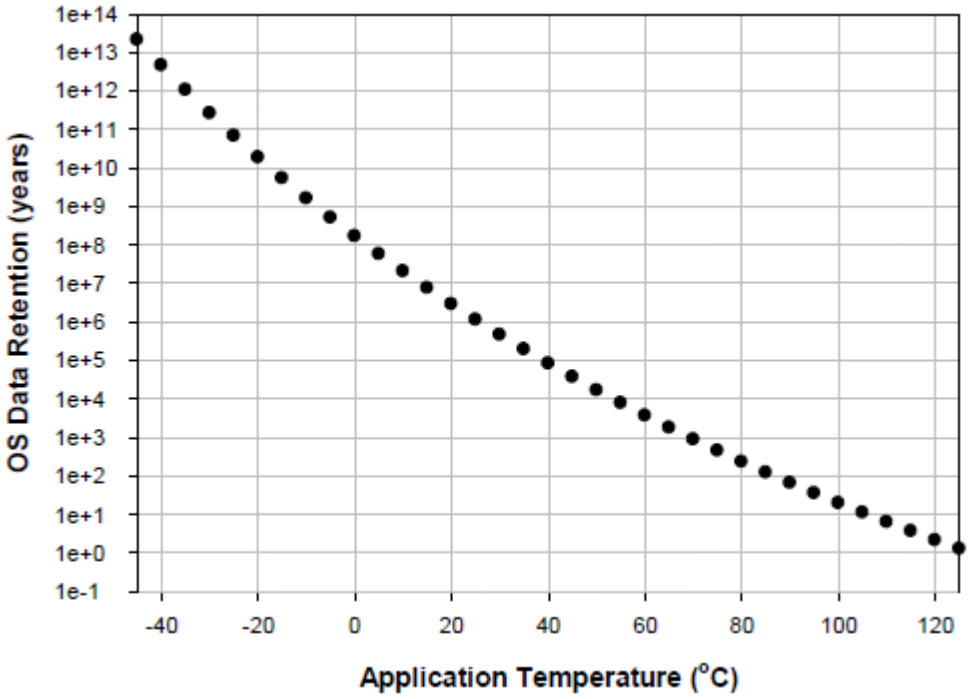

Figure 3. OS Retention Time of Automotive Grade 1 F-RAM at Various Temperatures

OS Retention Life Predication for Customized Temperature Profiles

Most of the previous sections focused on the OS data retention specification of AEC-Q100 Grade 1, Grade 2, or Grade 3 F-RAM at a fixed temperature. However, it is rare for an application to actually operate under a steady temperature for the entire usage life time of the application. Instead, an application is often expected to operate in multiple temperature environments throughout the application's usage life time. Accordingly, the retention specification for F-RAM in applications often needs to be calculated cumulatively.

For example: Assuming an application uses Grade 1 F-RAM at different temperature profiles over the following usage life time:

Temperature 1 = 125 ºC for 10% of time (t1)

Temperature 2 = 105 ºC for 15% of time (t2)

Temperature 3 = 85 ºC for 25% of time (t3)

Temperature 4 = 55 ºC for 50% of time (t4)

Following the Arrhenius equation, the acceleration factor A between T and Tmax is:

$$A = \frac{L(T)}{L(Tmax)} = e^{\frac{Ea}{k}\left(\frac{1}{T} - \frac{1}{Tmax}\right)}$$

Where 'k' is the Boltzmann constant 8.617 $\times 10^{-5}$ eV/K, Tmax is the highest temperature specified for the F-RAM product, and T is any temperature within the F-RAM product specification. All

temperatures are in Kelvin in the above equation. The acceleration factors are calculated and listed in Table 1.

Temperature	Time Factor	Acceleration Factor wrt Tmax	Profile Factor	Profile Life Time
(T)	(t)	(A)	(P)	L(P)
T1 = 125 ºC	t1 = 0.1	A1 = 1	$P=\frac{1}{\frac{t1}{A1}+\frac{t2}{A2}+\frac{t3}{A3}+\frac{t4}{A4}}$	$L(P) = P \times L(Tmax)$
T2 = 105 ºC	t2 = 0.15	A2 = 8.67		
T3 = 85 ºC	t3 = 0.25	A3 = 95.68		= 10.46 years
T4 = 55 ºC	t4 = 0.5	A4 = 6074.80	= 8.33	

Table 1. Acceleration Factors

The Profile factor P is determined by:

$$P=\frac{1}{\frac{t1}{A1}+\frac{t2}{A2}+\frac{t3}{A3}+\frac{t4}{A4}}$$

The OS retention life time prediction of a temperature profile, L(P), is given by:

$$L(P) = P \times L(Tmax)$$

Where L(Tmax) is the specified OS retention time 11,000 hours at 125 ºC. The calculation process and results are listed in Table 1. It can be observed that the life time of a profile is dominated by the highest usage temperature and its time factor. Note that in the calculation, T is equal to or lower than Tmax. It is mathematically correct to use in equations when T > Tmax, and T < Tmin; however Cypress does not guarantee the parts working properly when T is out of the temperature specifications.

Summary

Table 2 summarizes the Tmax, the OS retention life time specification at Tmax i.e., L(Tmax), and OS retention life time calculation of a general temperature profile.

F-RAM Product	Tmax	OS Retention at Tmax	OS Retention Life Time of Temperature Profile Determined by Customers
Grade 1	125 ºC	11 khours	$P = \frac{1}{\sum \frac{t}{A}}$, $L(P) = P \times L(Tmax)$
Grade 2	105 ºC	5 years	
Grade 3	85 ºC	10 years	

Table 2. Summary of OS Retention

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