Typical Data Retention for Nonvolatile Memory

By Martin Niset and Peter Kuhn
NVM Reliability
Austin, Texas

Introduction

This document explains how Freescale Semiconductor defines typical data retention in the product specification of nonvolatile memory (NVM).

Definition

Data retention refers to the ability of a memory bit to retain its data state over long periods of time regardless of whether the part is powered on or powered off.

Freescale Semiconductor guarantees a minimum data retention life in its product specification (generally 10 to 20 years). In practice, our technologies are capable of producing much longer lifetimes than the specified minimum. To give a better representation of the data retention life that can be achieved for most parts under nominal conditions, Freescale Semiconductor also provides a typical value in the product specification.

Freescale Semiconductor defines typical data retention by de-rating the intrinsic data retention capability of a technology to a normalized use condition.

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Definition

The intrinsic data retention is by definition inherent to all bits manufactured with the same process technology. It is an estimate, based on accelerated stress data and the Arrhenius model, of the data retention life that most bits are expected to achieve.

The Arrhenius model is an industry standard for estimating data retention life of floating gate technologies. It is used to find the acceleration factor between a stress temperature and a use condition, which in turn can be used to de-rate results from an accelerated stress test.

The temperature acceleration factor is defined as:

$$AF = \exp[(E_a/k) \cdot (1/T_{\text{Use}} - 1/T_{\text{Stress}})]$$

Where

- $E_a$ is the intrinsic activation energy (eV)
- $k$ is Boltzmann's constant ($8.617 \times 10^{-5}$ eV/K) ($K = -273.16°C$)
- $T_{\text{Use}}$ = use temperature (K)
- $T_{\text{Stress}}$ = stress temperature (K)

During the technology certification process, Freescale Semiconductor determines the intrinsic activation energy $E_a$ for a technology with empirical data. This is done by evaluating time-to-failure under high temperature stress.

Typical data retention at a nominal use condition is calculated using the Arrhenius model with the measured activation energy and accelerated stress data from one of the following:

- Technology certification
- Product qualification
- Wafer bake

Example

With a default activation energy of 0.8 eV,

- 1008 hours at 150°C (qualification bake time) is equivalent to 1150 years at 25°C
- 24 hours at 250°C (wafer bake time) is equivalent to 1800 years at 25°C
- 1008 hours at 150°C (qualification bake time) is equivalent to 60 years at 55°C
- 24 hours at 250°C (wafer bake time) is equivalent to 100 years at 55°C

1. Typically, extended bake on large sample at 150°C
2. Typically, 1008 hours at 150°C
3. Typically 250°C
4. $E_a = 0.8$ eV is a conservative estimate for the intrinsic activation energy supported by years of NVM experience. Freescale Semiconductor uses this value as the default activation energy for intrinsic data retention when empirical data are not available.
Typical Data Retention for Freescale Semiconductor NVM Technologies

Using the above definition, the following NVM technologies from Freescale Semiconductor are capable of achieving greater than 100 years of intrinsic data retention.

Table 1. Typical Data Retention Time Based on the Qualification Bake Time and the Activation Energy of Each Technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Ea (eV)</th>
<th>Minimum Specification</th>
<th>Qualification Stress</th>
<th>Typical Data Retention (Yr) @ 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Time (Yr)</td>
<td>Temp (°C)</td>
<td>Time (Hr)</td>
</tr>
<tr>
<td>CDR1</td>
<td>0.92(1)</td>
<td>10</td>
<td>85</td>
<td>1008</td>
</tr>
<tr>
<td>CDR3</td>
<td>1.2(1)</td>
<td>10/15</td>
<td>125/85</td>
<td>1008</td>
</tr>
<tr>
<td>0.5µm SGF</td>
<td>0.8(2)</td>
<td>15</td>
<td>125</td>
<td>504</td>
</tr>
<tr>
<td>0.25µm SGF</td>
<td>0.8(2)</td>
<td>15</td>
<td>85(3)</td>
<td>1008</td>
</tr>
</tbody>
</table>

NOTES:
1. Measured by Freescale Semiconductor
2. Default value
3. Average junction temperature
4. The following HCS12 devices use an earlier generation of the FLASH and are not covered by this engineering bulletin: MC9S12DT256B, MC9S12DJ256B, MC9S12A256B, MC9S12DG128B, MC9S12DJ128B, MC9S12DT128B, MC9S12A128B. These devices have, or will be, upgraded to current FLASH technology that is covered here and then will be available as MC9S12DT256, MC9S12DJ256, MC9S12A256, MC9S12DG128, MC9S12DJ128, MC9S12DT128, and MC9S12A128. Other devices using the earlier generation of the FLASH and not covered by this engineering bulletin are: MMC2114CFCVF33, MMC2114CFCPV33, MMC2114CFCPU33, MMC2113CFCVF33, MMC2113CFCPV33, MMC2113CFCPU33; DSP56F801, DSP56F802, DSP56F803, DSP56F805, DSP56F807, DSP56F826, and DSP56F827.
How to Reach Us:

Home Page:
www.freescale.com

E-mail:
support@freescale.com

USA/Europe or Locations Not Listed:
Freescale Semiconductor
Technical Information Center, CH370
1300 N. Alma School Road
Chandler, Arizona 85224
+1-800-521-6274 or +1-480-768-2130
support@freescale.com

Europe, Middle East, and Africa:
Freescale Halbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+49 89 92103 559 (German)
+49 89 92103 559 (English)
+33 1 69 35 48 48 (French)
support@freescale.com

Japan:
Freescale Semiconductor Japan Ltd.
Headquarters
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064
Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:
Freescale Semiconductor Hong Kong Ltd.
Technical Information Center
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T., Hong Kong
+800 2666 8080
support.asia@freescale.com

For Literature Requests Only:
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