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Quality and Reliability Report Overview

Silicon Labs is pleased to share this Quality and Reliability Report with our customers. It provides the latest quality performance data along with failure rate estimates and reliability monitor data for integrated circuit products.* These data are collected on a continual basis as qualification, production and reliability monitors are completed. The report is published and updated quarterly to provide customers visibility to the most recent information. The Quality Trend charts on page 5 are shown on a rolling five-year basis. All other reports include data from the previous four quarters on a rolling, one-year basis.

The report provides data covering:

- Estimates of shipped product quality
- Long-term operating life estimates
- Mean time to failure estimates
- Data retention life estimates
- Reliability monitor results

Silicon Labs is registered to ISO 9001:2015, ISO 14001:2015 and maintained certification to ISO/TS 16949:2009 from January 2008 to October 2014. Due to a change in the ISO/TS 16949 certification eligibility requirements in 2013, fabless semiconductor companies are no longer eligible for certification. Silicon Labs now conforms to IATF 16949 and continues to internally audit to IATF 16949 as well as being audited externally with IATF 16949 certified auditors. Silicon Labs uses IATF 16949 certified suppliers for automotive products.

Silicon Labs is committed to quality excellence. That commitment is demonstrated by extensive product and process qualification. Each product undergoes extensive qualification testing prior to production release. Silicon Labs qualifies integrated circuit products using JEDEC JESD47, Stress-Test-Driven Qualification of Integrated Circuits or AEC-Q100, Stress Test Qualification for Integrated Circuits, as appropriate.

Once a product is qualified, on-going product quality and reliability is verified through monitoring programs. Monitors are scheduled to periodically sample wafer fab technologies and package technologies. The results are published in this report. Any failures are used to drive corrective action and process and product improvement.

We hope you find this report useful. Please let us know if you have any specific questions or suggestions.

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*Module data will be added in 2020. Reliability qualification reports are available on www.silabs.com.
Average Outgoing Quality (AOQ)

Overview

Two elements of product quality are reported – electrical quality and mechanical/visual quality. We measure electrical quality by taking a sample (monitor) of production parts and retesting the sample to the datasheet limits (see Figure 1). The sample electrical test may be performed at an alternate test temperature to verify part performance across the datasheet temperature range. This sample method identifies defects introduced at the test process step or that have escaped the test process. Any failures drive corrective actions and product/process improvements.

Visual/Mechanical quality is estimated by sample inspection of the completed product prior to final pack. Inspection items cover a broad range of characteristics and include mark, count, label, cover tape workmanship, moisture barrier bag integrity, lead location, part placement, and many other general workmanship items required for customer satisfaction and product protection during shipment. Any failures drive corrective actions and process improvements.

Figure 1 – Quality Monitor Flow
Electrical and Visual / Mechanical Outgoing Quality Graphs

Silicon Labs Electrical AOQ

Silicon Labs Visual & Mechanical AOQ
# Part Numbers by Fab Technology

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Failure Rate Estimation by Fab Technology

Failure in Time (FIT)
A long-term, steady-state failure rate is often required by circuit and system engineers for allocations of the failure rates at the component level during system design. FIT, which stands for failure-in-time, is a widely-used term to describe failure rates of electronic components, and as used here, represents the number of failures in a billion hours of operation. FIT rates are reported in the following section as curves and in tables for specific temperatures and assumptions.

Mean Time to Failure (MTTF)
Another way to express failure rates is by mean time to failure (MTTF). MTTF is the inverse of the FIT rate and is useful for repair and maintenance planning. This relationship can be seen by examining the units of each measure: MTTF is given in time/failure; FIT is given in failure/time. MTTF is reported in the tables following the FIT rate curves for each specific fab technology.

Failure Rate Calculation Method
Long-term failure rates are estimated by applying the Arrhenius equation to data collected from long term operating life tests. A confidence factor is applied based upon the sample size and number of failures to estimate the maximum failure rate at a specific confidence level. The calculation details are provided in the table below each of the following FIT rate curves.
FIT Rate Curves and Data

Process – 40 nm

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]

FIT (90%)
FIT (60%)
Reliability FIT Calculations for temperature acceleration

**Single Point Calculation for 40 nm**

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<th>60%</th>
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<td>1000</td>
<td>Number of hours on stress</td>
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**Constants:**

|     | 8.61E-05 | 8.61E-05 | Boltzman's constant [eV/K] |

**Calculated Values:**

|     | 239.4    | 239.4    | Acceleration Factor: \[\exp(Ea/k(1/(Tja + 273.15) - (1/(Tjs + 273.15)))\] |
|     | 2.0      | 2.0      | degrees of freedom [2(F+1)] |
|     | 318816   | 318816   | Total device hours D*H |
|     | 4.6      | 1.8      | Chi-Square Distribution Value |
|     | 30.2     | 12.0     | Failures in time [failures / 1xE9 hours] |
|     |          |          | \[\frac{X^2}{(2*AF*DH)^*1E9}\] |
|     | 3.3E+07  | 8.3E+07  | Mean Time To Failure [hours] (Note: MTTF is 1/FIT) |
|     | 3783.5   | 9507.7   | Mean Time To Failure [years] (Note: MTTF is 1/FIT) |

**FIT Estimation Curves for 40 nm**

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<th>60% (yrs)</th>
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Process – 40 nm w/ embedded flash

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels
Reliability FIT Calculations for temperature acceleration

**Single Point Calculation for 40 nm w/ embedded flash**

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
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</thead>
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<tr>
<td>Tja [°C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [°C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [°C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
</tr>
<tr>
<td>Ea</td>
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<td>Energy Activation</td>
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<tr>
<td>D</td>
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<td>763</td>
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</tr>
<tr>
<td>H</td>
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<td>1000</td>
<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
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<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level (.1 = 90%; .4 = 60%)</td>
</tr>
</tbody>
</table>

**Constants:**

| k                  | 8.61E-05 | 8.61E-05 | Boltzmann's constant [eV/K] |

**Calculated Values:**

| Af                 | 239.4   | 239.4   | Acceleration Factor: \[\exp(\text{Ea}/k(1/(Tja + 273.15) - (1/(Tjs + 273.15)))\] |
| v                  | 2.0     | 2.0     | degrees of freedom \[2(F+1)\] |
| DH                 | 763016  | 763016  | Total device hours \[D*H\] |
| X²                 | 4.6     | 1.8     | Chi-Square Distribution Value |
| FIT                | 12.6    | 5.0     | Failures in time \[\text{failures / 1xE9 hours}\] |
| \[X²/(2*AF*D*H)*1E9\] |          |         | |
| MTTF               | 7.9E+07 | 2.0E+08 | Mean Time To Failure [hours] (Note: MTTF is 1/FIT) |
| MTTF               | 9055.0  | 22754.7 | Mean Time To Failure [years] (Note: MTTF is 1/FIT) |

**FIT Estimation Curves for 40 nm w/ embedded flash**

<table>
<thead>
<tr>
<th>Tja</th>
<th>Af</th>
<th>FIT (90%)</th>
<th>FIT (60%)</th>
<th>MTTF 90% (yrs)</th>
<th>MTTF 60% (yrs)</th>
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Process – 55 nm

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]
Reliability FIT Calculations for temperature acceleration

Single Point Calculation for 55 nm

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
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<tr>
<td>Tsa [C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
</tr>
<tr>
<td>Ea</td>
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<td>0.7</td>
<td>Energy Activation</td>
</tr>
<tr>
<td>D</td>
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</tr>
<tr>
<td>H</td>
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<td>Number of hours on stress</td>
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<tr>
<td>F</td>
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<td>2</td>
<td>Number of failures</td>
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<tr>
<td>P</td>
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Constants:

- k: 8.61E-05, 8.61E-05 Boltzmann constant [eV/K]

Calculated Values:

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<th>239.4</th>
<th>Acceleration Factor: [\exp(Ea/k*(1/(Tja + 273.15) - (1/(Tjs + 273.15)))]</th>
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<td>Failures in time [\text{failures} / 1\times 10^9 \text{hours}]</td>
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<tr>
<td>[X2/(2\times AF\times D\times H)\times 10^9]</td>
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<td>Mean Time To Failure [hours] (Note: MTTF is 1/FIT)</td>
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FIT Estimation Curves for 55 nm

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<td>168</td>
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Process – 90 nm w/ embedded flash

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]

FIT (90%)  FIT (80%)
Reliability FIT Calculations for temperature acceleration

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15C rise)</td>
</tr>
<tr>
<td>Ea</td>
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<td>0.7</td>
<td>Energy Activation</td>
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<tr>
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<td>2393</td>
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<td>Number of hours on stress</td>
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<td>Number of failures</td>
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<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [ 0.1 = 90%; 0.4 = 60%]</td>
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</table>

Constants:

- k = 8.61E-05 Boltzman’s constant [eV/K]

Calculated Values:

<table>
<thead>
<tr>
<th>AF</th>
<th>DH</th>
<th>X2</th>
<th>FIT</th>
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<tr>
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<td>7.8</td>
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</table>

- Acceleration Factor: \[\exp\left(\frac{Ea}{k}\left(\frac{1}{(Tja + 273.15)} - \left(\frac{1}{(Tjs + 273.15)}\right)\right)\right] \] 
- degrees of freedom \([2(F+1)]\)
- Total device hours \([D^H]\)
- Chi-Square Distribution Value
- Failures in time \([\text{failures} / 1x10^9 \text{hours}]\)
- \[=\left[X^2/(2^{AF}D^H)\right]^{1E9}\]

<table>
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<th>MTTF (90%)</th>
<th>MTTF (60%)</th>
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Mean Time To Failure [hours] (Note: MTTF is 1/FIT)

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<tr>
<th>Tja [C]</th>
<th>AF</th>
<th>FIT (90%)</th>
<th>FIT (60%)</th>
<th>MTTF (90%)</th>
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Process - 0.11 micron

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]

FIT (90%)
FIT (80%)
## Reliability FIT Calculations for temperature acceleration

### Single Point Calculation for 0.11 micron

<table>
<thead>
<tr>
<th>Variables</th>
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<th>Confidence Level</th>
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<td>50</td>
<td>Junction Temperature at operating condition</td>
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<tr>
<td>Tsa [°C]</td>
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<td>Tjs [°C]</td>
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### Constants:

- k = 8.61E-05 Boltzmann's constant [eV/K]

### Calculated Values:

- Af = 239.4 Acceleration Factor: \( \exp(\frac{Ea}{k}\times\frac{1}{Tja + 273.15} - \frac{1}{Tjs + 273.15}) \)
- \( \nu \) = 2.0 degrees of freedom \( 2(F+1) \)
- DH = 6915545 Total device hours \( D*H \)
- \( \chi^2 \) = 4.6 Chi-Square Distribution Value
- FIT = 1.4 Failures in time \( [\text{failures} \times 1\times 10^9 \text{hours}] \)
- MTTF = 7.2E+08 Mean Time To Failure [hours] (Note: MTTF is 1/FIT)
- MTTF = 82069.4 Mean Time To Failure [years] (Note: MTTF is 1/FIT)

### FIT Estimation Curves for 0.11 micron

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<tr>
<th>Tja</th>
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<th>FIT (60%)</th>
<th>MTTF (90% yrs)</th>
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Process - 0.13 micron

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]
Reliability FIT Calculations for temperature acceleration

### Single Point Calculation for 0.13 micron

<table>
<thead>
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<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
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<tr>
<td>Tsa [°C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
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<tr>
<td>Tjs [°C]</td>
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<td>140</td>
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<td>Confidence Level [0.1 = 90%; 0.4 = 60%]</td>
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</table>

### Constants:

- **k**: 8.61E-05, Boltzman's constant [eV/K]

### Calculated Values:

- **Af**: 239.4, 239.4, Acceleration Factor: \(\exp\left(\frac{Ea}{k}\times\left(\frac{1}{Tja + 273.15} - \left(\frac{1}{Tjs + 273.15}\right)\right)\right)\)
- **v**: 4.0, 4.0, degrees of freedom \(2(F+1)\)
- **DH**: 7936656, 7936656, Total device hours \(D^*H\)
- **X2**: 7.8, 4.0, Chi-Square Distribution Value
- **FIT**: 2.0, 1.1, Failures in time \(\text{[failures} / 1\times E9 \text{hours]}\)
  \( \text{FIT} = \frac{X2}{(2*AF*D^*H)*1E9} \)
- **MTTF**: 4.9E+08, 9.4E+08, Mean Time To Failure [hours] (Note: MTTF is 1/FIT)
- **MTTF**: 55755.8, 107240.7, Mean Time To Failure [years] (Note: MTTF is 1/FIT)

### FIT Estimation Curves for 0.13 micron

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<tr>
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Process - 0.15 micron

![Graph showing the failure rate as a function of junction temperature with estimated upper bound at two confidence levels.](image)
### Reliability FIT Calculations for temperature acceleration

#### Single Point Calculation for 0.15 micron

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<td>Tja [°C]</td>
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<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [°C]</td>
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<td>125</td>
<td>Ambient Temperature at stress</td>
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<tr>
<td>Tjs [°C]</td>
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<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
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<td>Ea</td>
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<td>Energy Activation</td>
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<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
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#### Constants:

- \( k = 8.61 \times 10^{-5} \) Boltzman's constant [eV/K]

#### Calculated Values:

- \( Af = 239.4 \) Acceleration Factor: \( \exp\left(\frac{Ea}{k} \left(\frac{1}{Tja + 273.15} - \frac{1}{Tjs + 273.15}\right)\right) \)
- \( v = 2.0 \) degrees of freedom \( [2(F+1)] \)
- \( DH = 104144 \) Total device hours \( D*H \)
- \( \chi^2 = 4.6 \) Chi-Square Distribution Value
- \( FIT = 92.4 \) Failures in time \( [\text{failures} / 1xE9 \text{ hours}] \)
  \[ = \frac{\chi^2}{(2*AF*D^*H)*1E9} \]
- \( MTTF = 1.1E+07 \) Mean Time To Failure [hours] (Note: \( MTTF = \frac{1}{FIT} \))
- \( MTTF = 1235.9 \) Mean Time To Failure [years] (Note: \( MTTF = \frac{1}{FIT} \))

#### FIT Estimation Curves for 0.15 micron

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</table>
Process - 0.18 micron

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]
### Reliability FIT Calculations for temperature acceleration

#### Single Point Calculation for 0.18 micron

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{ja}$ [°C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>$T_{sa}$ [°C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>$T_{js}$ [°C]</td>
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<tr>
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<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
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#### Constants:

| $k$                | 8.61E-05 | 8.61E-05 | Boltzman's constant [eV/K] |

#### Calculated Values:

| Af                | 239.4   | 239.4   | Acceleration Factor: $\exp\left(\frac{E_a}{k}\left(\frac{1}{T_{ja} + 273.15} - \frac{1}{T_{js} + 273.15}\right)\right)$ |
|-------------------|---------|---------| degrees of freedom $[2(F+1)]$ |
| $\nu$             | 2.0     | 2.0     | |
| $DH$              | 17977347| 17977347| Total device hours $D \times H$ |
| $X^2$             | 4.6     | 1.8     | Chi-Square Distribution Value |
| FIT               | 0.5     | 0.2     | Failures in time [failures / 1x10^9 hours] |
| $MTTF$            | 1.9E+09 | 4.7E+09 | Mean Time To Failure [hours] (Note: $MTTF = \frac{1}{FIT}$) |
| $MTTF$            | 213344.0| 536121.1| Mean Time To Failure [years] (Note: $MTTF = \frac{1}{FIT}$) |

#### FIT Estimation Curves for 0.18 micron

<table>
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<tr>
<th>$T_{ja}$ [°C]</th>
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<th>FIT (60%)</th>
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Process - 0.18 micron w/ embedded flash

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate vs. Junction Temperature [°C]
## Reliability FIT Calculations for temperature acceleration

### Single Point Calculation for 0.18 micron w/ embedded flash

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
</tr>
<tr>
<td>Ea</td>
<td>0.7</td>
<td>0.7</td>
<td>Energy Activation</td>
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<tr>
<td>D</td>
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<tr>
<td>H</td>
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<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
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<td>Number of failures</td>
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<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [0.1 = 90%; 0.4 = 60%]</td>
</tr>
</tbody>
</table>

### Constants:

| k         | 8.61E-05 | 8.61E-05 | Boltzman's constant [eV/K] |

### Calculated Values:

| Af        | 239.4 | 239.4 | Acceleration Factor: \[\exp(Ea/k*(1/(Tja + 273.15) - (1/(Tjs + 273.15)))\] |
| v         | 2.0   | 2.0   | degrees of freedom \[2(F+1)\] |
| DH        | 7008057 | 7008057 | Total device hours D*H |
| X2        | 4.6   | 1.8   | Chi-Square Distribution Value |
| FIT       | 1.4   | 0.5   | Failures in time \[\text{failures} / \text{1xE9 hours}\] |
| MTTF      | 7.3E+08 | 1.8E+09 | Mean Time To Failure [hours] (Note: MTTF is 1/FIT) |
| MTTF      | 83167.3 | 208994.5 | Mean Time To Failure [years] (Note: MTTF is 1/FIT) |

### FIT Estimation Curves for 0.18 micron w/ embedded flash

<table>
<thead>
<tr>
<th>Tja</th>
<th>Af</th>
<th>FIT (90%)</th>
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<th>90% (yrs)</th>
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Process - 0.18 micron w/ OTP

**Failure Rate as a Function of Junction Temperature**
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]
Reliability FIT Calculations for temperature acceleration

Single Point Calculation for 0.18 micron w/ OTP

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15C rise)</td>
</tr>
<tr>
<td>Ea</td>
<td>0.7</td>
<td>0.7</td>
<td>Energy Activation</td>
</tr>
<tr>
<td>D</td>
<td>3492</td>
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<td>Equivalent Devices stressed (Assuming 1000hrs per device)</td>
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<td>H</td>
<td>1000</td>
<td>1000</td>
<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
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<td>0</td>
<td>Number of failures</td>
</tr>
<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
</tr>
</tbody>
</table>

Constants:
- k = 8.61E-05 Boltzman's constant [eV/K]

Calculated Values:
- Af = 239.4
- v = 2.0
- DH = 3491552
- X2 = 4.6
- FIT = 2.8
- MTTF = 3.6E+08

MTTF = \[\frac{\text{X2}}{(2\text{AF} \times \text{D} \times \text{H}) \times 1E9}\]

FIT Estimation Curves for 0.18 micron w/ OTP

<table>
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<tr>
<th>Tja</th>
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<th>FIT (60%)</th>
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Process - 0.18 micron w/ RF

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]

FIT (90%)
FIT (60%)
### Reliability FIT Calculations for temperature acceleration

#### Single Point Calculation for 0.18 micron w/ RF

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
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<tr>
<td>Tja [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [C]</td>
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<td>140</td>
<td>Junction Temperature at stress (assume 15C rise)</td>
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<td>Ea</td>
<td>0.7</td>
<td>0.7</td>
<td>Energy Activation</td>
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<tr>
<td>D</td>
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<td>H</td>
<td>1000</td>
<td>1000</td>
<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
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<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
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#### Constants:

- **k** = 8.61E-05 Boltzman's constant [eV/K]

#### Calculated Values:

- **Af** = 239.4 239.4 Acceleration Factor: \[\exp\left(Ea/k \times \left(1/(Tja + 273.15) - (1/(Tjs + 273.15))\right)\right] \]
- **v** = 2.0 2.0 degrees of freedom [2(F+1)]
- **DH** = 2200683 2200683 Total device hours D*H
- **X2** = 4.6 1.8 Chi-Square Distribution Value
- **FIT** = 4.4 1.7 Failures in time [failures / 1xE9 hours]

- **MTTF** = 2.3E+08 5.7E+08 Mean Time To Failure [hours] (Note: MTTF is 1/FIT)
- **MTTF** = 26116.3 65628.8 Mean Time To Failure [years] (Note: MTTF is 1/FIT)

#### FIT Estimation Curves for 0.18 micron w/ RF

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<tr>
<th>Tja</th>
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<th>MTTF (90%)</th>
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Process - 0.25 micron

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]
Reliability FIT Calculations for temperature acceleration

### Single Point Calculation for 0.25 micron

**Variables:**
- 90%
- 60%
- Confidence Level
- $T_{ja} \, [C]$ 50 50  Junction Temperature at operating condition
- $T_{sa} \, [C]$ 125 125  Ambient Temperature at stress
- $T_{js} \, [C]$ 140 140  Junction Temperature at stress (assume 15°C rise)
- $E_a$ 0.7 0.7  Energy Activation
- $D$ 11709 11709  Equivalent Devices stressed (Assuming 1000hrs per device)
- $H$ 1000 1000  Number of hours on stress
- $F$ 0 0  Number of failures
- $P$ 0.1 0.4  Confidence Level [.1 = 90%; .4 = 60%]

**Constants:**
- $k$ 8.61E-05 8.61E-05  Boltzman's constant [eV/K]

**Calculated Values:**
- $A_f$ 239.4 239.4  Acceleration Factor: $[\exp(E_a k / (T_{ja} + 273.15) - (1/(T_{js} + 273.15))]$
- $v$ 2.0 2.0  degrees of freedom $[2(F+1)]$
- $D_H$ 11709015 11709015  Total device hours $D\times H$
- $X^2$ 4.6 1.8  Chi-Square Distribution Value
- $FIT$ 0.8 0.3  Failures in time $[\text{failures} / 1\times E^9\text{hours}]$
  
\[
FIT = \frac{X^2}{(2\times AF\times D\times H)\times 1E^9}
\]

$MTTF$ 1.2E+09 3.1E+09  Mean Time To Failure [hours] (Note: $MTTF$ is 1/FIT)

$MTTF$ 138955.3 349186.7  Mean Time To Failure [years] (Note: $MTTF$ is 1/FIT)

### FIT Estimation Curves for 0.25 micron

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Process - 0.25 micron w/ embedded flash

**Failure Rate as a Function of Junction Temperature**

*Estimated upper bound at two confidence levels*

- **FIT (90%)**
- **FIT (60%)**
### Reliability FIT Calculations for temperature acceleration

#### Single Point Calculation for 0.25 micron w/ embedded flash

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
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<td>50</td>
<td>Junction Temperature at operating condition</td>
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<tr>
<td>Tsa [°C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
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<tr>
<td>Tjs [°C]</td>
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<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
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<td>Energy Activation</td>
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<td>D</td>
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<td>2193</td>
<td>Equivalent Devices stressed (Assuming 1000hrs per device)</td>
</tr>
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<td>H</td>
<td>1000</td>
<td>1000</td>
<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>0</td>
<td>Number of failures</td>
</tr>
<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
</tr>
</tbody>
</table>

#### Constants:

- $k = 8.61 \times 10^{-5}$ Boltzmann's constant [eV/K]

#### Calculated Values:

- $A_f = 239.4$ Acceleration Factor: $\exp(Ea/k \times (1/(Tja + 273.15) - 1/(Tjs + 273.15)))$
- $v = 2.0$ degrees of freedom $[2(F+1)]$
- $DH = 2192540$ Total device hours $D'H$
- $X_2 = 4.6$ Chi-Square Distribution Value
- $FIT = 4.4$ Failures in time [failures / $1 \times E9$ hours]

- $MTTF = 2.3E+08$ Mean Time To Failure [hours] (Note: $MTTF = 1/FIT$)
- $MTTF = 26019.7$ Mean Time To Failure [years] (Note: $MTTF = 1/FIT$)

#### FIT Estimation Curves for 0.25 micron w/ embedded flash

<table>
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<tr>
<th>Tja</th>
<th>Af</th>
<th>FIT (90%)</th>
<th>FIT (60%)</th>
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*Note: FIT Estimation Curves for 0.25 micron w/ embedded flash are provided for reference and may require further context or data for accurate interpretation.*
Process – 0.315 - 0.35 micron

**Failure Rate as a Function of Junction Temperature**

*Estimated upper bound at two confidence levels*

![Graph showing failure rate as a function of junction temperature.](image-url)
Reliability FIT Calculations for temperature acceleration

Single Point Calculation for 0.315 um - 0.35 um

Variables:
- Tja [°C]: 50 50 Junction Temperature at operating condition
- Tsa [°C]: 125 125 Ambient Temperature at stress
- Tjs [°C]: 140 140 Junction Temperature at stress (assume 15°C rise)
- Ea: 0.7 0.7 Energy Activation
- D: 1058 1058 Equivalent Devices stressed (Assuming 1000hrs per device)
- H: 1000 1000 Number of hours on stress
- F: 0 0 Number of failures
- P: 0.1 0.4 Confidence Level [.1 = 90%; .4 = 60%]

Constants:
- k: 8.61E-05 8.61E-05 Boltzman's constant [eV/K]

Calculated Values:
- Af: 239.4 239.4 Acceleration Factor: \[\exp\left(\frac{Ea}{k}\left(\frac{1}{Tja + 273.15} - \frac{1}{Tjs + 273.15}\right)\right)\]
- v: 2.0 2.0 degrees of freedom [2(F+1)]
- DH: 1058304 1058304 Total device hours D*H
- $X^2$: 4.6 1.8 Chi-Square Distribution Value
- FIT: 9.1 3.6 Failures in time \([\text{failures} / \text{1xE9 hours}]\)
\[=\frac{X^2}{(2\cdot AF\cdot D^*H)\cdot 1E9}\]
- MTTF: 1.1E+08 2.8E+08 Mean Time To Failure [hours] (Note: MTTF is 1/FIT)
- MTTF: 12559.3 31560.8 Mean Time To Failure [years] (Note: MTTF is 1/FIT)

FIT Estimation Curves for 0.315 um - 0.35 um

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Process - 0.35 micron

![Graph: Failure Rate as a Function of Junction Temperature](image)
Reliability FIT Calculations for temperature acceleration

Single Point Calculation for 0.35 micron

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{ja}$ [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>$T_{sa}$ [C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>$T_{js}$ [C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15C rise)</td>
</tr>
<tr>
<td>$E_a$</td>
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<td>0.7</td>
<td>Energy Activation</td>
</tr>
<tr>
<td>$D$</td>
<td>2920</td>
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<td>Equivalent Devices stressed (Assuming 1000hrs per device)</td>
</tr>
<tr>
<td>$H$</td>
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<td>1000</td>
<td>Number of hours on stress</td>
</tr>
<tr>
<td>$F$</td>
<td>2</td>
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<td>Number of failures</td>
</tr>
<tr>
<td>$P$</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
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</table>

Constants:

- $k$ = 8.61E-05 Boltzmann's constant [eV/K]

Calculated Values:

- $A_f$ = 239.4 239.4 Acceleration Factor: $[\exp(E_a/k*(1/(T_{ja} + 273.15) - (1/(T_{js} + 273.15))))]
- $v$ = 6.0 6.0 degrees of freedom $[2(F+1)]$
- $D^H$ = 2919808 2919808 Total device hours $D^H$
- $X_2$ = 10.6 6.2 Chi-Square Distribution Value
- FIT = 7.6 4.4 Failures in time $[\text{failures / 1x10^9 hours}]
= [X_2/(2*AF*D^H)*1E9]$
- MTTF = 1.3E+08 2.3E+08 Mean Time To Failure [hours] (Note: MTTF is 1/FIT)
- MTTF = 14990.8 25692.7 Mean Time To Failure [years] (Note: MTTF is 1/FIT)

FIT Estimation Curves for 0.35 micron

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<th>FIT (60%)</th>
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<th>MTTF 60% (yrs)</th>
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</table>
Process - 0.35 micron w/ embedded flash

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]
### Reliability FIT Calculations for temperature acceleration

**Single Point Calculation for 0.35 micron w/ embedded flash**

<table>
<thead>
<tr>
<th>Variables</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15C rise)</td>
</tr>
<tr>
<td>Ea</td>
<td>0.7</td>
<td>0.7</td>
<td>Energy Activation</td>
</tr>
<tr>
<td>D</td>
<td>1862</td>
<td>1862</td>
<td>Equivalent Devices stressed (Assuming 1000hrs per device)</td>
</tr>
<tr>
<td>H</td>
<td>1000</td>
<td>1000</td>
<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>2</td>
<td>Number of failures</td>
</tr>
<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [ .1 = 90%;  .4 = 60%]</td>
</tr>
</tbody>
</table>

**Constants:**

- \( k = 8.61E-05 \) | 8.61E-05 | Boltzmann’s constant [eV/K]

**Calculated Values:**

- \( Af = 239.4 \) | 239.4 | Acceleration Factor: \([\exp(Ea/(k*(1/(Tja + 273.15)) - (1/(Tjs + 273.15))))]\)
- \( v = 6.0 \) | 6.0 | degrees of freedom \([2(F+1)]\)
- \( DH = 1861504 \) | 1861504 | Total device hours \(D^*H\)
- \( X2 = 10.6 \) | 6.2 | Chi-Square Distribution Value
- \( FIT = 11.9 \) | 7.0 | Failures in time [failures / 1x10^9 hours]
- \( MTTF = 8.4E+07 \) | 1.4E+08 | Mean Time To Failure [hours] (Note: MTTF is 1/FIT)
- \( MTTF = 9557.3 \) | 16380.2 | Mean Time To Failure [years] (Note: MTTF is 1/FIT)

### FIT Estimation Curves for 0.35 micron w/ embedded flash

<table>
<thead>
<tr>
<th>Tja</th>
<th>Af</th>
<th>FIT (90%)</th>
<th>FIT (60%)</th>
<th>MTTF (90% yrs)</th>
<th>MTTF (60% yrs)</th>
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<tbody>
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</table>
Process - 0.45 - 0.5 um SPTM

**Failure Rate as a Function of Junction Temperature**
**Estimated upper bound at two confidence levels**

![Graph showing failure rate as a function of junction temperature.](image)
Reliability FIT Calculations for temperature acceleration

### Single Point Calculation for 0.45 - 0.5 um SPTM

<table>
<thead>
<tr>
<th>Variables:</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [°C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [°C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [°C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
</tr>
<tr>
<td>Ea</td>
<td>0.7</td>
<td>0.7</td>
<td>Energy Activation</td>
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<tr>
<td>D</td>
<td>526</td>
<td>526</td>
<td>Equivalent Devices stressed (Assuming 1000hrs per device)</td>
</tr>
<tr>
<td>H</td>
<td>1000</td>
<td>1000</td>
<td>Number of hours on stress</td>
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<tr>
<td>F</td>
<td>0</td>
<td>0</td>
<td>Number of failures</td>
</tr>
<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [0.1 = 90%; .4 = 60%]</td>
</tr>
</tbody>
</table>

### Constants:

| k          | 8.61E-05 | 8.61E-05 | Boltzmann's constant [eV/K] |

### Calculated Values:

<table>
<thead>
<tr>
<th>Af</th>
<th>239.4</th>
<th>239.4</th>
<th>Acceleration Factor: [\exp\left(\frac{Ea}{k}\left(\frac{1}{Tja + 273.15} - \frac{1}{Tjs + 273.15}\right)\right)]</th>
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<td>v</td>
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<td>2.0</td>
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<td>526064</td>
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### FIT Estimation Curves for 0.45 - 0.5 um SPTM

<table>
<thead>
<tr>
<th>Tja</th>
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<th>FIT (60%)</th>
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Process - 0.6 - 1.0um

![Graph showing failure rate as a function of junction temperature.](image)
Reliability FIT Calculations for temperature acceleration

Single Point Calculation for 0.6 - 1.0um

<table>
<thead>
<tr>
<th>Variables:</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [°C]</td>
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<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
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<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [°C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
</tr>
<tr>
<td>Ea</td>
<td>0.7</td>
<td>0.7</td>
<td>Energy Activation</td>
</tr>
<tr>
<td>D</td>
<td>582</td>
<td>582</td>
<td>Equivalent Devices stressed (Assuming 1000hrs per device)</td>
</tr>
<tr>
<td>H</td>
<td>1000</td>
<td>1000</td>
<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>0</td>
<td>Number of failures</td>
</tr>
<tr>
<td>P</td>
<td>0.1</td>
<td>0.4</td>
<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
</tr>
</tbody>
</table>

Constants:

k     8.61E-05 8.61E-05 Boltzman's constant [eV/K]

Calculated Values:

Af     239.4 239.4 Acceleration Factor: \[\exp\left(\frac{Ea}{k}\left(\frac{1}{Tja + 273.15} - \frac{1}{Tjs + 273.15}\right)\right)\]

v     2.0 2.0 degrees of freedom \[2(F+1)\]

DH    582487 582487 Total device hours \(D \times H\)

\(X^2\) 4.6 1.8 Chi-Square Distribution Value

FIT    16.5 6.6 Failures in time \([\text{failures} / 1 \times 10^9 \text{hours}]\)

\(\text{MTTF} = \frac{X^2 \times (2 \times AF \times D \times H) \times 1 \times 10^9}{(2 \times AF \times D \times H)}\)

\(\text{MTTF} = 6.1E+07 1.5E+08\) Mean Time To Failure [hours] (Note: MTTF is 1/FIT)

\(\text{MTTF} = 6912.6 17370.9\) Mean Time To Failure [years] (Note: MTTF is 1/FIT)

FIT Estimation Curves for 0.6 - 1.0um

<table>
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<tr>
<th>Tja [°C]</th>
<th>Af</th>
<th>FIT (90%)</th>
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<th>MTTF 90% (yrs)</th>
<th>MTTF 60% (yrs)</th>
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Process – Diode

Failure Rate as a Function of Junction Temperature
Estimated upper bound at two confidence levels

FIT Rate

Junction Temperature [°C]
## Reliability FIT Calculations for temperature acceleration

### Single Point Calculation for Diode

<table>
<thead>
<tr>
<th>Variables:</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
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<tr>
<td>Tja [C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
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<tr>
<td>Tsa [C]</td>
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<td>Ambient Temperature at stress</td>
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<td>Tjs [C]</td>
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<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
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<td>0.7</td>
<td>Energy Activation</td>
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<td>188</td>
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<td>H</td>
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<td>Number of hours on stress</td>
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<td>F</td>
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<td>0</td>
<td>Number of failures</td>
</tr>
<tr>
<td>P</td>
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<td>0.4</td>
<td>Confidence Level [0.1 = 90%; 0.4 = 60%]</td>
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### Constants:

- k = 8.61E-05 8.61E-05 Boltzman's constant [eV/K]

### Calculated Values:

- Af = 239.4 239.4 Acceleration Factor: \[\exp\left(\frac{\text{Ea}}{k}\left(\frac{1}{\text{Tja} + 273.15} - \frac{1}{\text{Tjs} + 273.15}\right)\right)\]
- v = 2.0 2.0 degrees of freedom \[2(F+1)\]
- DH = 187703 187703 Total device hours \(D\times H\)
- X² = 4.6 1.8 Chi-Square Distribution Value
- FIT = 51.2 20.4 Failures in time \[\text{failures} \times 1\times E9 \text{hours}\]

\[\text{FIT} = \frac{X²}{(2\times AF \times D\times H) \times 1E9}\]

###MTTF:

- MTTF = 2.0E+07 4.9E+07 Mean Time To Failure [hours] (Note: MTTF is 1/FIT)
- MTTF = 2227.5 5597.7 Mean Time To Failure [years] (Note: MTTF is 1/FIT)

### FIT Estimation Curves for Diode

<table>
<thead>
<tr>
<th>Tja</th>
<th>Af</th>
<th>FIT (90%)</th>
<th>FIT (60%)</th>
<th>MTTF 90% (yrs)</th>
<th>MTTF 60% (yrs)</th>
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Process - High Voltage

**Failure Rate as a Function of Junction Temperature**
Estimated upper bound at two confidence levels

![Graph showing failure rate as a function of junction temperature](image)

- **FIT (90%)**
- **FIT (80%)**

Junction Temperature [°C]

FIT Rate
Reliability FIT Calculations for temperature acceleration

### Single Point Calculation for High Voltage

<table>
<thead>
<tr>
<th>Variables:</th>
<th>90%</th>
<th>60%</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tja [°C]</td>
<td>50</td>
<td>50</td>
<td>Junction Temperature at operating condition</td>
</tr>
<tr>
<td>Tsa [°C]</td>
<td>125</td>
<td>125</td>
<td>Ambient Temperature at stress</td>
</tr>
<tr>
<td>Tjs [°C]</td>
<td>140</td>
<td>140</td>
<td>Junction Temperature at stress (assume 15°C rise)</td>
</tr>
<tr>
<td>Ea</td>
<td>0.7</td>
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<td>Energy Activation</td>
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<tr>
<td>D</td>
<td>7129</td>
<td>7129</td>
<td>Equivalent Devices stressed (Assuming 1000hrs per device)</td>
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<tr>
<td>H</td>
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<td>Number of hours on stress</td>
</tr>
<tr>
<td>F</td>
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<td>2</td>
<td>Number of failures</td>
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<tr>
<td>P</td>
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<td>0.4</td>
<td>Confidence Level [.1 = 90%; .4 = 60%]</td>
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</table>

### Constants:

| k                 | 8.61E-05 | Boltzman's constant [eV/K] |

### Calculated Values:

- **Af**: Acceleration Factor: \[ \exp \left( \frac{Ea}{k} \times \left( \frac{1}{Tja + 273.15} - \frac{1}{Tjs + 273.15} \right) \right) \]
- **v**: degrees of freedom \[ 2(F+1) \]
- **DH**: Total device hours \[ D \times H \]
- **X2**: Chi-Square Distribution Value
- **FIT**: Failures in time \[ \frac{X2}{2(2AF \times DH) \times 1E9} \]
- **MTTF**: Mean Time To Failure \[ \frac{1}{FIT} \]

### FIT Estimation Curves for High Voltage

<table>
<thead>
<tr>
<th>Tja</th>
<th>Af</th>
<th>FIT (90%)</th>
<th>FIT (60%)</th>
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<th>MTTF</th>
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Flash Reliability Summary by Fab Technology
### 40 nm Flash Reliability Summary

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<th>10 Year Predicted Failure Rate Ta=50°C, 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
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#### Data Retention Reliability

**MTTF (Years)**

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#### Data Retention Reliability

**Continuous Use Fallout (%)**

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<td>0%</td>
</tr>
<tr>
<td>75</td>
<td>0%</td>
</tr>
<tr>
<td>80</td>
<td>0%</td>
</tr>
<tr>
<td>85</td>
<td>0%</td>
</tr>
<tr>
<td>90</td>
<td>0%</td>
</tr>
<tr>
<td>95</td>
<td>0%</td>
</tr>
<tr>
<td>100</td>
<td>0%</td>
</tr>
<tr>
<td>105</td>
<td>0%</td>
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<td>110</td>
<td>0%</td>
</tr>
<tr>
<td>115</td>
<td>0%</td>
</tr>
<tr>
<td>120</td>
<td>0%</td>
</tr>
<tr>
<td>125</td>
<td>0%</td>
</tr>
</tbody>
</table>
### 90 nm Flash Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,923,664</td>
<td>0</td>
<td>1.6</td>
<td>0.014%</td>
<td>12.7</td>
<td>0.111%</td>
</tr>
</tbody>
</table>

#### Data Retention Reliability

![Data Retention Reliability Plot](image)

- MTTF (Years) vs. Use Temperature [°C]
- Data Retention Reliability

#### Continuous Use Fallout

![Continuous Use Fallout Plot](image)

- 5 Year Continuous Use Fallout (%) vs. Use Temperature [°C]
## 0.11um OTP Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,257,196</td>
<td>0</td>
<td>1.2</td>
<td>0.011%</td>
<td>9.5</td>
<td>0.083%</td>
</tr>
</tbody>
</table>

### Data Retention Reliability

![Graph showing data retention reliability over use temperature](image_url)

### Data Retention Reliability

#### Continuous Use Fallout

![Graph showing 5-year continuous use fallout over use temperature](image_url)
## 0.13um Flash Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C, 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C, 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>160,000</td>
<td>0</td>
<td>40.1</td>
<td>0.351%</td>
<td>312.1</td>
<td>2.697%</td>
</tr>
</tbody>
</table>

### Data Retention Reliability

**MTTF (Years)** vs **Use Temperature [°C]**

### Data Retention Reliability

**Continuous Use Fallout** vs **Use Temperature [°C]**

---

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0.13um OTP Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>9,050,665</td>
<td>0</td>
<td>0.7</td>
<td>0.006%</td>
<td>5.5</td>
<td>0.048%</td>
</tr>
</tbody>
</table>

Data Retention Reliability

MTTF (Years)

Data Retention Reliability

Continuous Use Fallout

5 Year Continuous Use Fallout (%)
## 0.18um Flash Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>27,228,808</td>
<td>6</td>
<td>1.9</td>
<td>0.017%</td>
<td>14.7</td>
<td>0.129%</td>
</tr>
</tbody>
</table>

### Data Retention Reliability

![Graph showing Data Retention Reliability](image)

### Data Retention Reliability

**Continuous Use Fallout**

- **5 Year Continuous Use Fallout (%)**
  - **Use Temperature [°C]**
    - **MTTF (Years)**
      - **Data Retention Reliability**
0.18um OTP Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,125,798</td>
<td>0</td>
<td>0.5</td>
<td>0.004%</td>
<td>3.5</td>
<td>0.031%</td>
</tr>
</tbody>
</table>

Data Retention Reliability

Data Retention Reliability Continuous Use Fallout

Quarterly Quality & Reliability Report  | 20Q3_QR_Report
0.25um HDR Flash Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C, 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C, 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,831,033</td>
<td>0</td>
<td>1.1</td>
<td>0.010%</td>
<td>8.6</td>
<td>0.075%</td>
</tr>
</tbody>
</table>

Data Retention Reliability

Data Retention Reliability
Continuous Use Fallout
## 0.35um HE Flash Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,371,053</td>
<td>0</td>
<td>2.7</td>
<td>0.024%</td>
<td>21.1</td>
<td>0.184%</td>
</tr>
</tbody>
</table>

### Data Retention Reliability

#### MTTF (Years)

![MTTF Graph](image)

#### Use Temperature [C]

#### Data Retention Reliability

#### Continuous Use Fallout

![Continuous Use Fallout Graph](image)
0.35um Non-HE Flash Reliability Summary

<table>
<thead>
<tr>
<th>Effective Dev-Hrs at 150°C</th>
<th>Chargeable Failures</th>
<th>Typical Case: Predicted FIT @Ta=50°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=50°C 60% UCL</th>
<th>Worst Case: Predicted FIT @Ta=85°C, 60% UCL</th>
<th>10 Year Predicted Failure Rate Ta=85°C 60% UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,671,366</td>
<td>0</td>
<td>0.7</td>
<td>0.006%</td>
<td>5.8</td>
<td>0.050%</td>
</tr>
</tbody>
</table>

Data Retention Reliability

Data Retention Reliability
Continuous Use Fallout

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Reliability Monitors

Overview

Once a product is qualified, we verify continued product reliability with a reliability monitor program. The monitor program is scheduled to periodically sample wafer fab and package technologies. The results are published in this report. Any failures are used to drive corrective action and product and process improvement.

Stress Descriptions

Silicon Labs follows JEDEC as the preferred industry standard. The most common reliability tests and conditions are listed in the following table. The specific JEDEC documents are available on the Internet at www.jedec.org.

Reliability Tests, Procedures and Conditions Table

<table>
<thead>
<tr>
<th>Stress Name</th>
<th>Stress Procedure</th>
<th>Standard Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR</td>
<td>Data Retention Bake</td>
<td>AEC-Q100; 150°C (pkg form); 250°C (wafer)</td>
</tr>
<tr>
<td>ELFR</td>
<td>Early Life Failure Rate</td>
<td>JEDEC JESD22-A108; 125°C; Max operating voltage</td>
</tr>
<tr>
<td>HAST</td>
<td>Highly-Accelerated Temperature and Humidity Stress Test</td>
<td>JEDEC JESD22-A110; 130°C; 85%RH; 22.2 psia; biased</td>
</tr>
<tr>
<td>HTB</td>
<td>High Temperature Bake</td>
<td>JEDEC JESD22-A103; 150°C</td>
</tr>
<tr>
<td>LTOL</td>
<td>Low Temperature Operating Life</td>
<td>JEDEC JESD22-A108; -10°C; Max operating voltage</td>
</tr>
<tr>
<td>HTOL</td>
<td>High Temperature Operating Life</td>
<td>JEDEC JESD22-A108; 125°C; Max operating voltage</td>
</tr>
<tr>
<td>PC</td>
<td>Preconditioning</td>
<td>JEDEC JESD22-A113; According to MSL level prior to package stresses (listed below)</td>
</tr>
<tr>
<td>TC</td>
<td>Temperature Cycle</td>
<td>JEDEC JESD22-A104; Condition C: -65 to 150°C</td>
</tr>
<tr>
<td>U-HAST</td>
<td>Unbiased HAST</td>
<td>JEDEC JESD22-A118; 130°C; 85%RH</td>
</tr>
<tr>
<td>THB</td>
<td>Temperature Humidity Bias</td>
<td>JEDEC JESD22-A101; 85°C; 85%RH; Max operating voltage</td>
</tr>
</tbody>
</table>

Qualification Guideline: Stress Test Driven Qualification of Integrated Circuits; EIA / JEDEC EIA/JESD47 / AEC-Q100
Silicon Reliability Test Method and Conditions

**Early Life Failure Rate (ELFR)**

The purpose of this test is to simulate the user operation over the first portion of the product lifetime, also called early life. Silicon Labs typically uses dynamic conditions, meaning the device is powered up, and the inputs are toggled to exercise a maximum number of transistors and circuit area. Reliability acceleration is accomplished primarily by temperature and secondarily by voltage.

**High Temperature Operating Life (HTOL)**

The purpose of this test is to simulate the user part operation over the expected life of the product. We typically use dynamic conditions, meaning the device is powered up, and the inputs are toggled to exercise a maximum number of transistors and circuit area. Reliability acceleration is accomplished primarily by temperature and secondarily by voltage.

**High Temperature Storage Life (HTSL) / High Temperature Bake (HTB)**

The purpose of this test is to determine the effect of storage at elevated temperature. This is performed to assess the stability of semiconductor device materials and interfaces.

**Low Temperature Operating Life (LTOL)**

The purpose of this test is to simulate the user operation at low temperature. This is a specialized test to address specific fab failure mechanisms, such as hot-carrier injection. Wafer level reliability tests are more effective for this characterization and are the primary qualification method. Silicon Labs typically uses dynamic conditions, meaning the device is powered up, and the inputs are toggled to exercise a maximum number of transistors and circuit area.

**Nonvolatile Memory Data Retention (DR)**

The purpose of this test is to measure the ability of a nonvolatile memory cell to retain its charge state at elevated temperature in the absence of applied external bias. This test can be done either in wafer form or on packaged units.
### Reliability Monitor Report – Silicon Stresses

<table>
<thead>
<tr>
<th>QLotNum</th>
<th>Stress</th>
<th>Fab Process</th>
<th>Read Date</th>
<th>Sample Size</th>
<th>Read Pt</th>
<th>Fails</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q046266</td>
<td>HTOL</td>
<td>0.11 um</td>
<td>21-Aug-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td>Q045819</td>
<td>HTSL</td>
<td>0.11 um</td>
<td>11-May-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q046626</td>
<td>HTSL</td>
<td>0.11 um</td>
<td>29-Jul-20</td>
<td>25</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q046630</td>
<td>HTSL</td>
<td>0.11 um</td>
<td>29-Jul-20</td>
<td>25</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q046634</td>
<td>HTSL</td>
<td>0.11 um</td>
<td>29-Jul-20</td>
<td>25</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q044496</td>
<td>HTOL</td>
<td>0.13 um</td>
<td>02-Oct-19</td>
<td>88</td>
<td>1000</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>Q044908</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>17-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045075</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>25-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045076</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>25-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045077</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>25-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045078</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>25-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q044891</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>30-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>Q044887</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>31-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>Q044900</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>08-Nov-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q044939</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>04-Dec-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045706</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>19-Mar-20</td>
<td>26</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045707</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>19-Mar-20</td>
<td>26</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045708</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>19-Mar-20</td>
<td>26</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045731</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>16-Apr-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045775</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>21-Apr-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045719</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>29-Apr-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045783</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>01-Jun-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q046108</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>25-Jun-20</td>
<td>25</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q046109</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>25-Jun-20</td>
<td>25</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q046144</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>25-Jun-20</td>
<td>25</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045763</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>29-Jun-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q046078</td>
<td>HTSL</td>
<td>0.13 um</td>
<td>16-Jul-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>125</td>
</tr>
<tr>
<td>Q045787</td>
<td>HTSL</td>
<td>0.13 um, embedded flash</td>
<td>01-Jun-20</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045285</td>
<td>ELFR</td>
<td>0.18 um</td>
<td>26-Nov-19</td>
<td>501</td>
<td>48</td>
<td>0</td>
<td>103</td>
</tr>
<tr>
<td>Q045549</td>
<td>ELFR</td>
<td>0.18 um</td>
<td>30-Dec-19</td>
<td>504</td>
<td>48</td>
<td>0</td>
<td>97</td>
</tr>
<tr>
<td>Q045207</td>
<td>HTDR</td>
<td>0.18 um</td>
<td>04-Dec-19</td>
<td>42</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045293</td>
<td>HTOL</td>
<td>0.18 um</td>
<td>18-Nov-19</td>
<td>82</td>
<td>500</td>
<td>0</td>
<td>97</td>
</tr>
<tr>
<td>Q044895</td>
<td>HTSL</td>
<td>0.18 um</td>
<td>13-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q044916</td>
<td>HTSL</td>
<td>0.18 um</td>
<td>21-Oct-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045204</td>
<td>HTSL</td>
<td>0.18 um</td>
<td>18-Nov-19</td>
<td>28</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>Q045143</td>
<td>HTSL</td>
<td>0.18 um</td>
<td>17-Dec-19</td>
<td>80</td>
<td>1000</td>
<td>0</td>
<td>150</td>
</tr>
<tr>
<td>QLotNum</td>
<td>Stress</td>
<td>Fab Process</td>
<td>Read Date</td>
<td>Sample Size</td>
<td>Read Pt</td>
<td>Fails</td>
<td>°C</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
<td>------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------</td>
<td>-------</td>
<td>----</td>
</tr>
<tr>
<td>Q045739</td>
<td>HTSL</td>
<td>0.18 um</td>
<td>15-Apr-20</td>
<td>80</td>
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*Quarterly Quality & Reliability Report | 20Q3_QR_Report*
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Package Reliability Test Method and Conditions

Preconditioning (PC)
This test method is performed to simulate the various shipping conditions, the end use environment and customer board mounting process for a given packaging system. Preconditioning is an industry standard flow for non-hermetic (plastic) integrated circuit packages that is representative of a typical industry solder reflow operation. The test parts are subject to bake, moisture soak and three reflow cycles prior to being submitted to package reliability testing.

Temperature Cycling (TC)
This test evaluates potential reliability degradation due to thermal cycling effects. Devices are placed in a chamber using forced air to cycle devices between the specified temperature extremes. This test is conducted to determine the ability of components and solder interconnects to withstand mechanical stresses induced by alternating high and low temperature extremes. Permanent changes in electrical and/or physical characteristics can result from these mechanical stresses.

Temperature Humidity and Bias (THB)
This test evaluates the reliability of non-hermetic packaged integrated circuits in humid environments. It employs severe conditions of temperature, humidity and bias to accelerate the penetration of moisture through the external protective material (encapsulant) or along the interface between the external protective material and the metallic conductors passing through it. This test is less accelerated than autoclave and unbiased HAST and takes longer to complete. It provides more realistic results in line with actual field performance. The dominant failure mechanism is aluminum corrosion accelerated by moisture, bias and contamination.

Highly-Accelerated Temperature and Humidity Stress Test (HAST)
This test evaluates the reliability of non-hermetic packaged integrated circuits in humid environments. It employs severe conditions of temperature, humidity, and bias which accelerate the penetration of moisture through the external protective material (encapsulant or seal) or along the interface between the external protective material and the metallic conductors which pass through it. The stress usually activates the same failure mechanisms as the “85/85” Temperature Humidity and Bias (THB) test.

Unbiased Highly-Accelerated Stress Test (U-HAST)
This test is performed to evaluate the reliability of non-hermetic packaged integrated circuits in humid environments. It is an alternate to Autoclave and tests for the same failure mechanisms. It employs severe conditions of temperature, humidity, and pressure to accelerate the penetration of moisture through the external protective material (encapsulant) or along the interface between the external protective material and the metallic conductors passing through it. UHAST is preferred over the autoclave stress method due to the reduction in artifacts induced by the 100%rh environment of autoclave, such as lead corrosion or contamination transfer by liquid water. The dominant failure mechanism is corrosion of internal materials.
Reflow Profile and Moisture Sensitivity Level

Overview

Non-hermetic (plastic) integrated circuit packages are classified by moisture sensitivity level per IPC/JEDEC J-Std-020. It is critical for final product quality that the board assembly process account for package moisture sensitivity, especially the peak reflow temperature and the maximum manufacturing expose time (MET).

Reflow Profile

Non-hermetic integrated circuit SMD (surface mount devices) are qualified in compliance to the applicable reflow profiles provided in IPC/JEDEC J-STD-020. The board assembler should not exceed the limits defined in the reflow profile tables of IPC/JEDEC J-STD-020.

Moisture Sensitivity Level

The Moisture Sensitivity Level (MSL) and peak reflow temperature are indicated on each product packing label.
### Reliability Monitor Report – Package Stresses

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